SEPTEMBER 1958

Agricultural Engineering

The Journal of the American Society of Agricultural Engineers

why

what

where

when

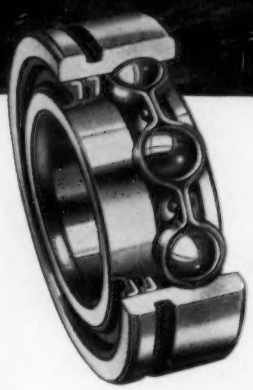
How

ND FACTS

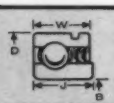
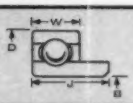
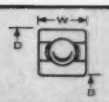
LUBRICATED-FOR-LIFE DISC BEARINGS CUT MAINTENANCE ON PLOWS

Disc plows mounted with New Departure integrally sealed, factory-lubricated ball bearings require NO field servicing. In fact, no grease fitting is provided or even needed. With New Departure ball bearings, discs turn freely, wear evenly and longer. They remain fully adjusted . . . assuring no unplowed furrows. And . . . with field adjustment eliminated, there's never a danger of bearing contamination.

Photo: Courtesy of J. I. Case Co.

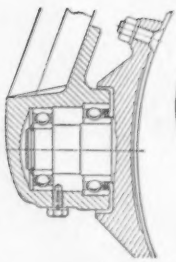


DIMENSIONS

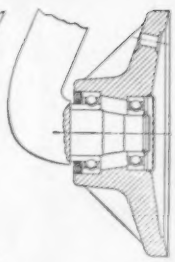
TYPE I  TYPE II  TYPE III 

Plow Size*	Position	Bearing Number	Type	Bore B	Diameter D	Width W	Width J
24 RS	Front	905422	I	1.6250	3.2677	1.014	1.024
24 RS	Rear	3207	III	1.3780	2.8346	.669	—
24 SS	Front	3208	III	1.5748	3.1496	.709	—
24 SS	Rear	905422	I	1.6250	3.2677	1.014	1.024
28 RS	Front	4510 A	II	1.9685	3.5433	.787	1.297
28 RS	Rear	3208	III	1.5748	3.1496	.709	—
28 SS	Front	3208	III	1.5748	3.1496	.709	—
28 SS	Rear	4510 A	II	1.9685	3.5433	.787	1.297
32 RS	Front	3L13	III	2.5591	3.9370	.709	—
32 RS	Rear	3210	III	1.9685	3.5433	.787	—
32 SS	Front	3210	III	1.9685	3.5433	.787	—
32 SS	Rear	3L14	III	2.7559	4.3307	.787	—

*RS indicates rotating spindle; SS indicates stationary spindle



Rotating spindle disc plow mounting featuring a two lip integral seal bearing.



Stationary spindle disc plow mounting featuring extended inner race for mounting external seal.

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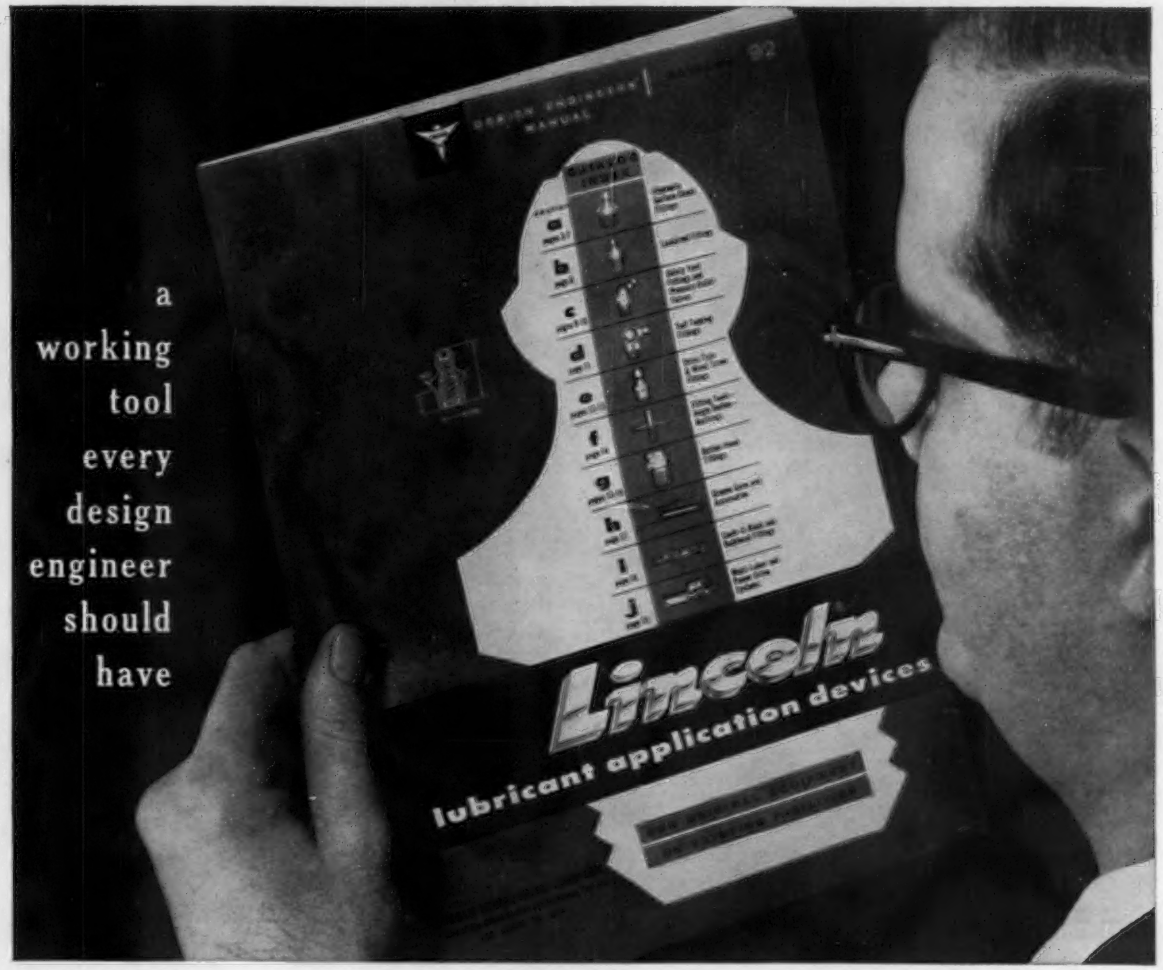

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Agricultural Engineering

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Cover Design

THE cover design of this issue is the work of ASAE member Phil F. Wendell, who was among the first industry men to take up the challenge offered by "system farming" advocates.

When asked to reveal the story he tells with silhouettes rather than words, and how he arrived at his final design, he responded with the following account:

"When I was invited to design the cover for the Materials Handling issue three ideas offered interesting possibilities. First, and rejected immediately, was an Artzybiosheff treatment with allegorical maws and orifices, clutching fingers and rumbling belly; you understand that some equipment applications have struck me like that at times.

PHIL F. WENDELL

"Second, and speedily rejected, was a schematic depiction of a cow's innards rendered in drafting board style. Anyone who has ever dissected a cow will recognize the elements of basic materials handling.

"However, the final decision was to play the design straight. Unfortunately the subject is so complex it could only be approached symbolically.

"From their central vantage point Editors Seferovich, DeForest *et al* have long viewed this subject as being like a satellite project. To achieve the orbitting of system farming, which is the ultimate and inevitable goal, there must be two-stage force. I think everyone will agree that Stage One embraces the reasoning and analyses of Why, What, Where, and When. Therefore Stage One embraces those engineers, economists, specialists, advisors, editors and thinking educators who vanguard our project.

"Stage Two is represented by the How people who carry the project on into actual application at the working site. To do this they have facilities such as experience and knowledge, production people and tools.

"The subject is without limit. You compound all the Stage One factors by the Stage Two factors. And then it gets really fascinating when you again start to compound to *n*ths of agricultural variables contained in the categories of non-flow, free-flow, and liquid plus sizes, locations, timing, *ad infinitum*.

"So, in a sense, this cover was designed by all of us. As the executionist(?) my intent is to stimulate more interest, and certainly the membership of ASAE is the most fertile ground to strike."

Through a student background at University of Cincinnati (industrial engineering) and University of Wisconsin (design), and later career work in commercial art and sales management, Phil Wendell moved into agricultural interests by way of engineering. Farm materials handling and systemization, and Wendell, collided through a fortunate series of circumstances involving his employer's position as a manufacturer of farm elevators, and exposure to the thinking of agricultural engineers Hall, Buelow, Cargill, White and others at Michigan State University, and McKenzie, Isaacs and others at Purdue University.

By 1955 his drawings and writing were influencing the application levels. Industrially the tail was beginning to wag the dog, he says. In 1957, he wrote and illustrated a complete technical guide on farm materials handling equipment and methods.

Wendell is now free-lancing, specializing in technical application layouts for industrial clients. He lives, as he tells it, halfway between Michigan State and Purdue at Burr Oak, Mich., with two young sons who want to be Ag Engineers, two daughters who want to be teachers, and his wife who already is.

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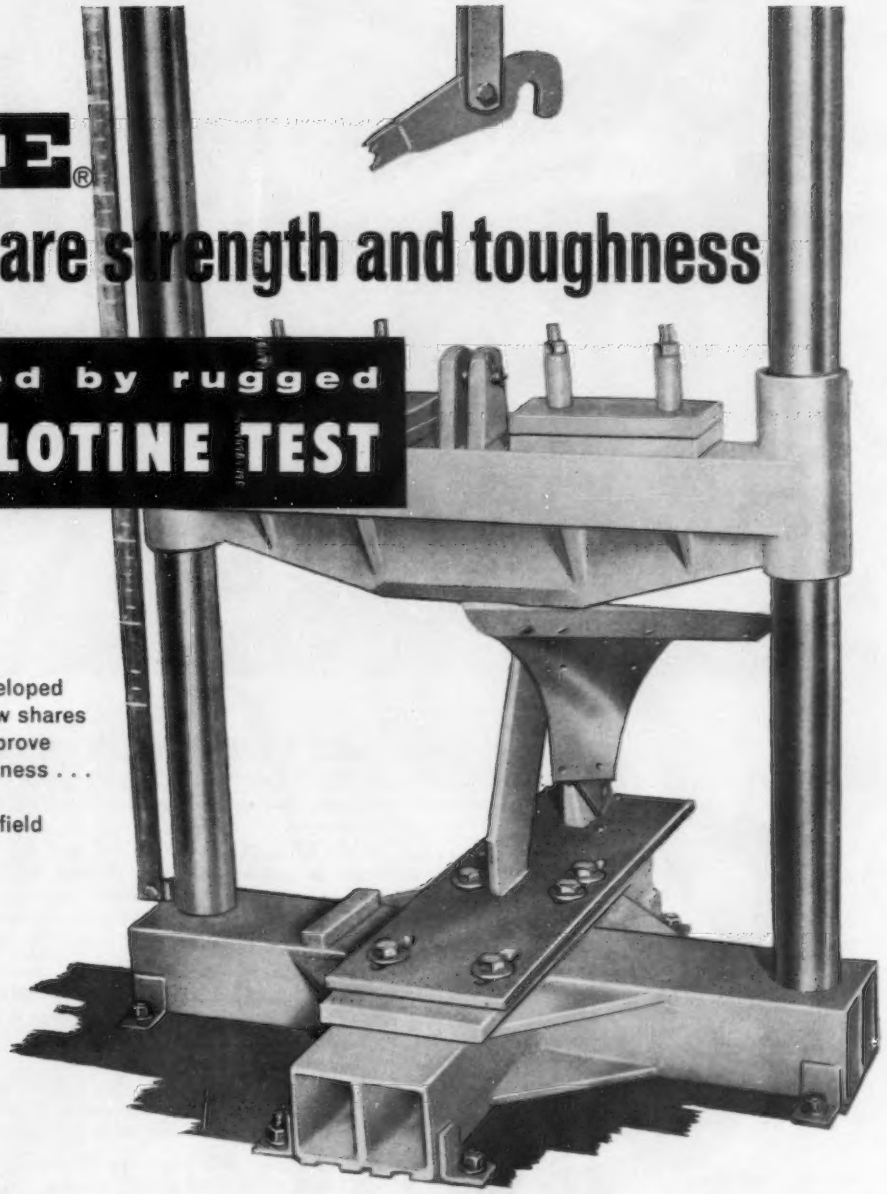

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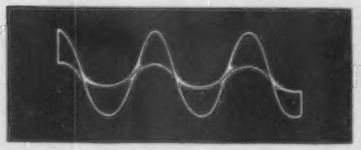

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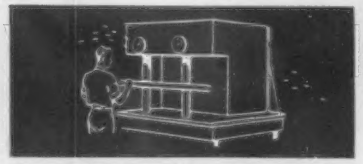

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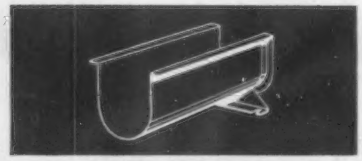

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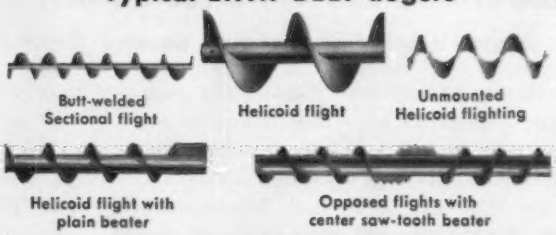

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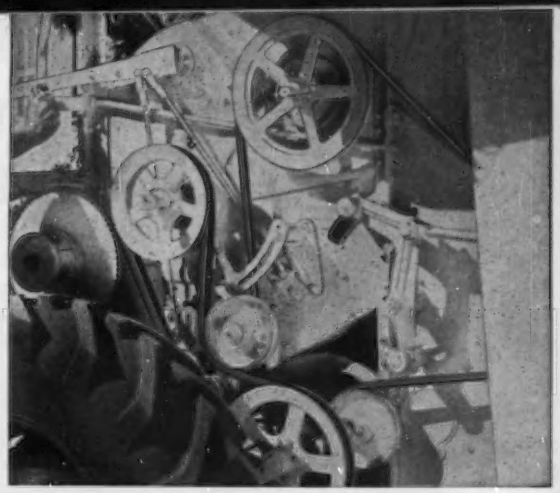
Possibly a Dayton B.S.I. or one of the complete line of Dayton Agricultural V-Belts is the answer to your power transmission problem. It's worth your while to find out by writing The Dayton Rubber Co., Agricultural O.E.M. Div., Dayton 1, Ohio.

*Back Side Idler



The Case "120" saves hours of time when grain is ready. Equipped with a concave clearance indicator, adjustments for various crops can be made quickly and easily for maximum harvesting efficiency. A variety of special cylinder speeds are available for harvesting beans, grasses, vegetable and flower seeds, flax and other crops.

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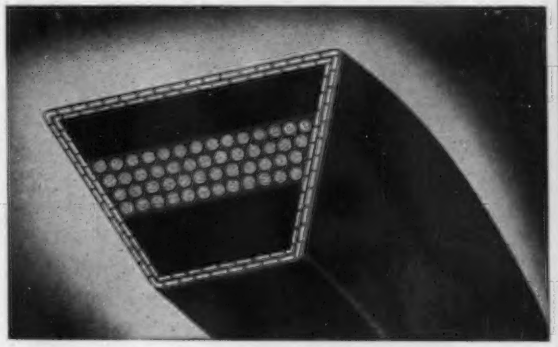

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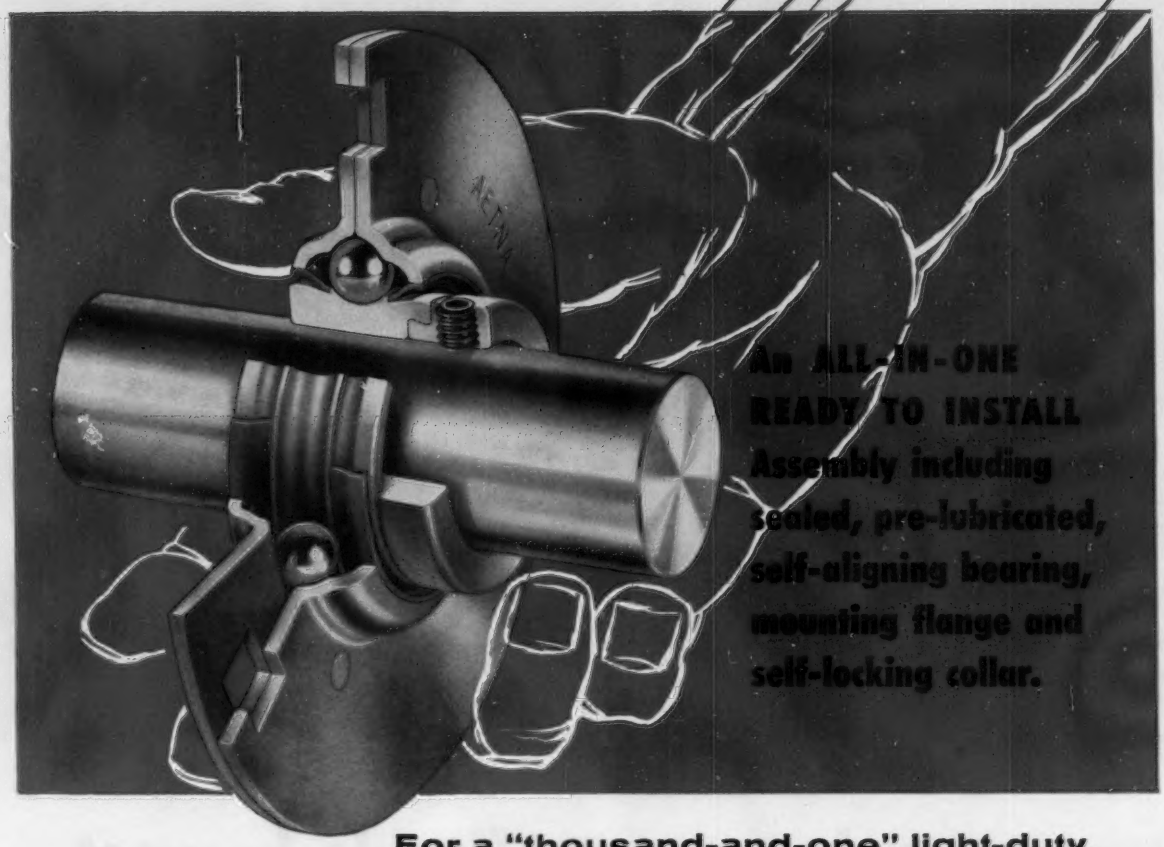

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Report to Readers . . .

"ROBOT CULTIVATOR" PUTS AUTOMATION NEARER IN PRODUCTION OF CORN CROP

Anything that relieves operators of the close concentration and intense fatigue that go with cultivating corn or other row crops with motorized equipment deserves to rate as a distinct achievement. Ford electronic and agricultural engineers have been doing something about the problem in their study to speed up the cultivating operation and make it semi-automatic. . . . . Their efforts have led them to develop what they call a "robot cultivator." Its key feature is a pivoted, hairpin-shaped "feeler" that touches the corn or other plant, serving like an insect's antennae to locate the plant's position in the row. If the plant is to the right or left of the center line of the feeler, the latter moves in the direction of the plant as the cultivator nears it. This direction of movement of the feeler is transmitted through miniature microswitches to a small servomotor attached to the power-steering linkage of the tractor. The linkage is automatically lengthened or shortened to direct tractor travel so the cultivator is centered as it passes each plant. . . . . Steering correction is automatic, with no attention from the operator. He can override the device at any time, but he never needs to touch the steering wheel while the equipment is moving down the crop row. . . . . Big advantage of the robot cultivator is that, by removing the fatigue element, the speed of cultivation can be much faster - up to 5½ to 6 mph, say the engineers. Also, the robot idea can be used with either front or rear-mounted cultivators.

"ENGINEERING" VS "TECHNOLOGY" - CALL TO ACTION BY ENGINEERS

Engineers Joint Council, of which the ASAE is a member, reports a matter of special interest to all engineers. EJC's public relations committee is much concerned on account of the continued references in the press, on radio and television, in advertising, and in statements out of Washington and elsewhere, which generally use the phrase "science and technology" rather than the more accurate designation "science and engineering." EJC urges its member societies - and that of course includes the individual members thereof - to help rectify this faux pas by calling attention to it whenever and wherever it occurs and recommending use of the proper (preferred) phrase, "engineering and science.". . . . EJC's appeal merits the individual approval and response of the readers of this journal. "The wheel that squeaks the loudest is the wheel that gets the grease."

LAND BENCHES CONSERVE RAINFALL RUNOFF AND CHECK EROSION ON SEMIARID LANDS

A new kind of contour terracing that appears to hold much promise for checking soil erosion and conserving rainfall runoff from semiarid lands is being made the subject of a special study by USDA researchers. Briefly, this new type of terracing consists of wide, level benches separated by still wider strips of natural slope. . . . . At the USDA field station near Amarillo, Tex., the engineers constructed four level benches which were separated by unleveled strips of land that contribute runoff water to the benches. The ratio of contributing area to bench area was two to one. At the time of the first seeding, the soil on the benches held more than double the available water on the contributing areas. Grain yield on the benches was double that on the contributing area. Additional tests will be made to more fully evaluate the feasibility of "contour benching". . . . The first test, however, indicates that wide land benches create natural reservoirs for runoff, and the engineers hope that increased production from the land may more than offset the cost of construction involved.

USDA AGRICULTURAL ENGINEERS WARN AGAINST OBSOLESCENT FARM BUILDINGS

The engineering specialists in farm buildings in the U S Department of Agriculture have been making what might be termed an "agonizing reappraisal" of farm buildings. Presumably they have mostly in mind the generally admitted inadequacy of many of the older buildings now on farms to meet the fast-moving changes taking place in agriculture generally. As a result of a survey directed to hundreds of farmers and other people having a direct interest in agriculture, the consensus of the USDA engineers is that farm buildings for tomorrow's requirements must be highly efficient and more readily adaptable to a rapidly changing agriculture. Increasing mechanization in the handling of materials in and around farm buildings will require far more efficient but not excessively costly ways and means for materials handling. This will in turn call for many new and improved concepts of buildings to adequately meet the new requirements. . . . . This issue of AGRICULTURAL ENGINEERING is devoted exclusively to new concepts and developments in farm-materials handling, and particularly to the mechanization aspects thereof. Herein lies one of the big, new engineering challenges in agriculture.

CROP-TOPPING CONCEPT AN OUTGROWTH OF HIGH-CLEARANCE EQUIPMENT DEVELOPMENT

Indications are that henceforth many corn fields in the fall will take on the tonsorial effect of a "flat top." Anyway watch for "crop topping," as many farmers identify it, to meet with increasing favor. . . . . It appears that farmer interest in crop topping springs largely from the development of high-clearance farm equipment by one manufacturer (Hagie). . . . . With high-clearance topping equipment, the tops of corn plants are cut and allowed to fall between the rows. The important advantages of this is that it hastens maturity of the crop, speeds drying, helps to eliminate lodging, and improves the efficiency of mechanical picking. Last year farmers who topped their corn found that the crop stood up better and that, with a reduced amount of leaves and stalks, they were able to do a better job of picking. Also it was possible to increase the travel speed of pickers considerably in topped corn.

ENGINEERS DEVELOP UTILITY BUILDING FOR CROP DRYING

For the most part, crop driers now in use have been specially designed for the particular farms on which they are located. Some of these driers are suitable for drying only one or two crops, and oftentimes have proven not to be large enough for a farm's needs. . . . . However, agricultural engineers at the University of Wisconsin believe they have overcome this handicap in a new crop-drying building they have developed. With this building several different crops can be dried during a single season. Moreover, it has the advantage of being able to handle a large crop with little labor. . . . . This experimental building is 44 feet long by 20 feet wide, and it has a 14-foot sidewall. A center duct divides it into two 20-foot square bins. The source of heat for drying is a portable crop drier, which is located in a 12x16-foot shed near the drying building. . . . . This building has the capacity for drying 20 tons of chopped hay in 24 hours. In one case, with 1500 bushels of oats in the bins, the moisture content of the grain dropped from 22 to 12 percent in 24 hours. Thus far 17,000 bushels of shelled corn have been dried in this experimental building. It will handle 2,000 bushels at one time. The conveyors built under the floor carry the dried crop to storage. . . . . While this crop-drying building is still in the experimental stage, results of its use thus far would indicate it may well prove to be an outstanding advance in the development of farm crop-drying equipment.

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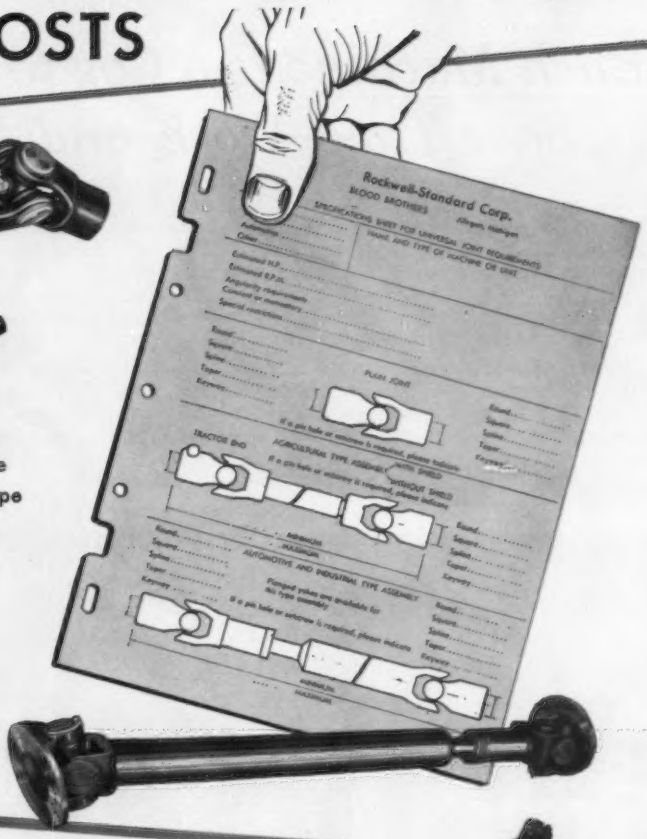

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UNIVERSAL JOINTS
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John Deere Gears Design of Related

Each Machine Is a Cog to Increase Efficiency ... Save Time, Work, and Money

It's no longer enough to design a particular machine to do one particular job. John Deere engineers believe that efficient farming demands a system of handling crops from field to storage, matching the capacities of related machines. Each machine is an integral part of a system—and it's the system that saves time, work, and money for the farmer.

John Deere engineers point with pride to many outstanding examples of materials-handling. For instance, take the exclusive One-Man Way of Making Hay that eliminates at least 50 per cent of the labor formerly required to put up hay crops . . .

Or, John Deere's introduction of Corn Combining and related equipment for drying and storing of grain crops . . .

Or, how about John Deere's Mechanical Pasturing Equipment for chopping, feeding, and storing forage crops.

There are more: Six-Row Farming, Matched Manure-Handling Equipment, and many others. These highly efficient systems all answer the challenge of farm labor scarcity, high production costs, and increased acreages. These systems make money for farmers.

ONE-MAN WAY of MAKING HAY

The last of the grueling jobs on the farm bit the dust with John Deere's introduction of One-Man Hay Making. The heavy lifting and handling are gone—and at tremendous savings for every owner.

The revolutionary Bale Ejector Attachment for all John Deere Twine-Tie Balers permits the tractor driver alone to bale and load hay crops automatically. All costly extra field help is eliminated.

Elevator equipment teamed with the John Deere Barn Bale Conveyor stores bales automatically. Bales are distributed through the full length of the mow without stacking. The bales are approximately half-size and tumble into place in the mow all the way up to conveyor height.

Half-sized bales offer many advantages. They not only load themselves in the wagon and store themselves in the barn but they are easier to unload at the elevator and easier to handle at feeding time.

Machines to Materials-Handling Systems

COMBINING, DRYING, and STORING CORN

JOHN DEERE'S introduction of the corn combine was another first—an innovation that opened the door to better corn harvests at reduced costs. The John Deere Corn Combine saves more corn by reducing shelling . . . permits earlier harvesting . . . gains an earlier market . . . saves on equipment costs . . . saves on the cost of combining small grains . . . and saves on storage costs. Bonus advantages include cleaner corn, easier handling.

Now, John Deere follows up with the big-capacity, portable Grain Dryer that permits you to take full advantage of corn combining early when moisture content is high. The John Deere Grain Dryer handles 100 to 300 bushels per hour—keeps the crop moving to storage in a hurry.

Of course, the highly portable John Deere Elevator finishes the storage job anywhere on the farm, eliminating back-breaking labor.

CHOPPING, FEEDING, and STORING FORAGE

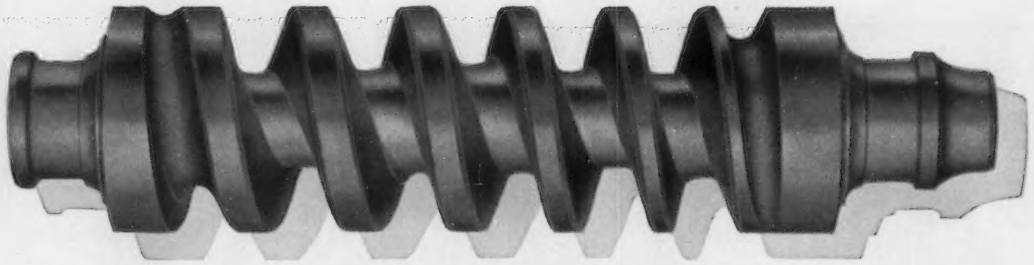
FEEDERS and dairymen find a cost-cutting system ready and waiting in John Deere Equipment. Mechanical pasturing (bringing the pasture to the cows) is fast and easy with the flail-type John Deere 15 Rotary Chopper and Self-Unloading 110 Chuck Wagon Mixer-Feeder, mounted on either wagon gear or truck bed.

Other John Deere Forage Harvesters are available for handling corn as well as hay crops and a powerful Forage Blower puts crops to bed in a hurry.

A self-unloading Forage Box Attachment for the John Deere Model "N" PTO Manure Spreader is also available for speedy, efficient handling of chopped materials.

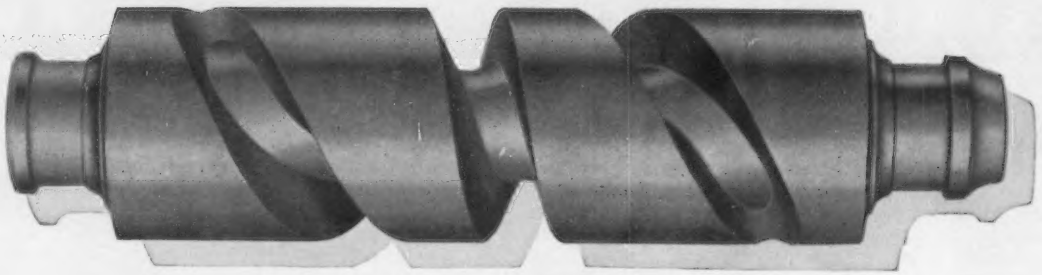
JOHN DEERE
MOLINE, ILLINOIS

Tale of Two Steering Cams



Constant ratio 22:22:22 . . . 22 to 1 ratio for cornering and 22 to 1 for straight-ahead driving . . . 5 turns of steering wheel from lock to lock.

Variable ratio 12:20:12 . . . 12 to 1 ratio for cornering and 20 to 1 for straight-ahead handling . . . 3 turns of wheel from lock to lock.



. . . Constant Ratio and Variable Ratio

Ross

▶ Yes, these two cams tell a Ross engineering story of *alert steering response* and *greater maneuverability* for vehicles of many different types:

Passenger Cars	Farm Machinery
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▶ The two vastly different cams also help dramatize the fact that Ross provides a gear for every steering need, power or manual, variable or constant ratio. Variable ratio steering was originated and developed by Ross.

▶ Ross invites discussion of *any* steering problem.

STEERING

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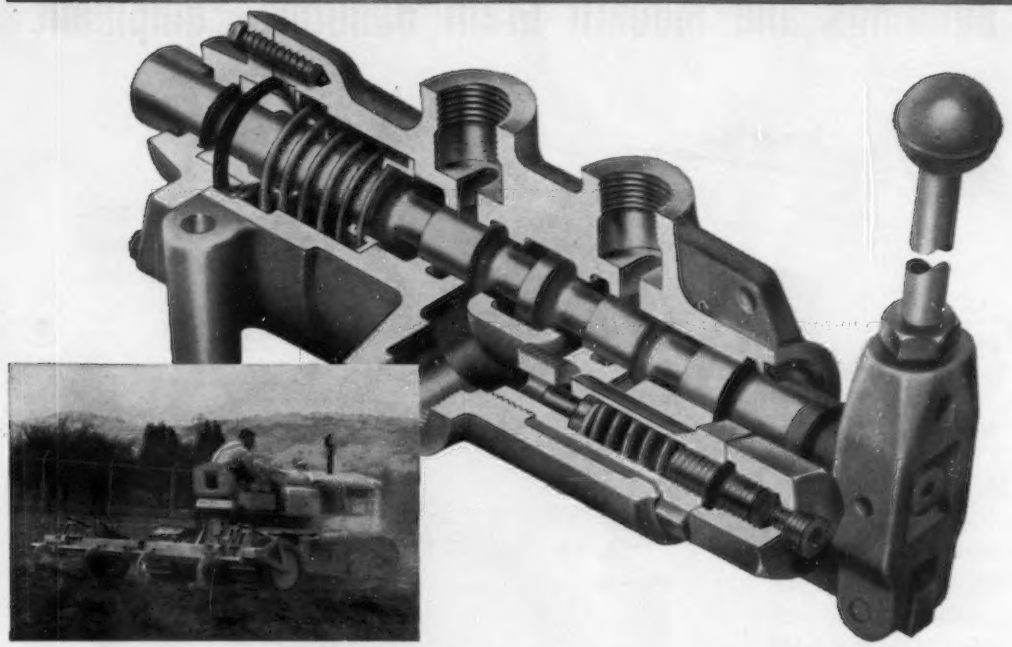
NATIONAL OIL SEAL LOGBOOK



Use of O-rings as moving seal in heavy duty bulldozer control valve

1,500 psi variation without backup rings. Intermittent operation plus long periods of inactivity. Extreme external dust and dirt conditions. Irregular and unpredictable field servicing. Fluid oil temperatures reaching 180°F. Climatic temperature extremes from —30° to +120°F. Life expectancy is required to be that of the tractor.

Above are the rugged operating conditions faced and met by National industrial O-rings in the new Be-Ge Model SU-1200F bulldozer blade control valve. A total of four rings are employed in each unit; two in a moving shaft application and two as static seals.

Be-Ge reports no leakage or ring failure on hundreds of heavy duty applications involving Oliver, Caterpillar, International Harvester and other crawler tractor installations.

National offers a complete line of industrial O-rings, plus many exclusive compounds. Special compounding is also available to meet unusual conditions.

For complete information on National O-Rings, or for skilled O-ring engineering service, call your nearest National Seal engineer. In major cities nationwide. See the Yellow Pages, under "Oil Seals".

Syntech® Oil Seals

Syntech oil seals, developed by and offered exclusively by National, are widely used synthetic rubber seals for applications where temperatures reach 250°F, speeds reach 3,600 FPM, and total indicator runout is as high as .030. Basic 50,000 series Syntech (illustrated) employs a tough, accurately manufactured steel outer case, precision-tensioned spring and accurately molded and trimmed Syntech sealing lip.

Micro-Torc Oil Seals

Micro-torc oil seals, pioneered by National, are sturdy, dependable leather seals. Special elastomer coating on *surface* of chrome re-tanned leather sealing lip prevents seepage of oil. Yet inner body of sealing lip retains natural porosity to "store" lubricant against accidental periods of starvation. Inherent lubricity of elastomer coating produces a lower torque, longer lasting, economical oil seal. Available in a wide variety of types and sizes.

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Division, Federal-Mogul-Bower Bearings, Inc.
General Offices: Redwood City, California
Plants: Van Wert, Ohio, Redwood City and Downey, California

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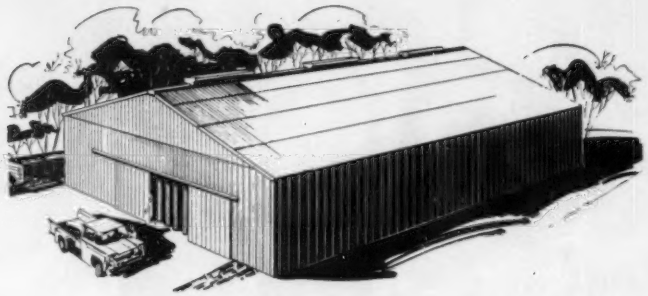
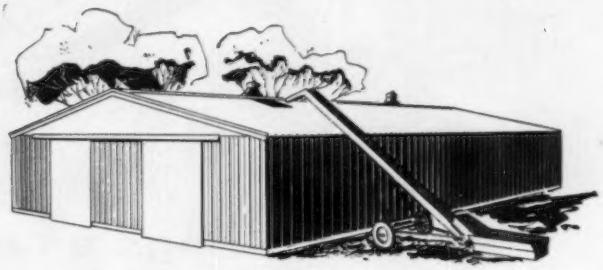
Here's The Best Way To Store Grain...

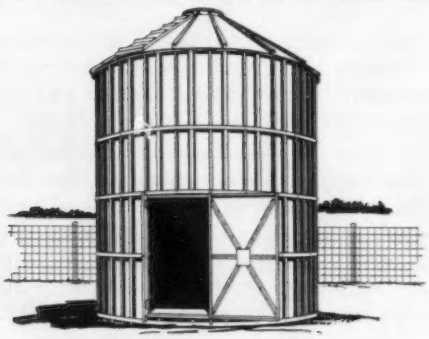
Armco Buildings and Modern Grain Handling Equipment



20′ high Armco Grain Storage Buildings are designed for large volume storage (24,500 bushels and up) plus off-season duty.

Many on-farm storage needs are met with 10′ and 12′ high Armco Grain Storage Buildings in the size range from 20 to 60 feet wide. (Capacities 4,000 bushels and up.) Typical example is this 40′ wide Armco Building.





Armco Grain Bins have STEELOX interlocking panel wall construction. They are extremely tight; easy to erect. 60% fewer parts than ordinary bin.

Flat grain storage is no longer a temporary measure. It can be permanent and efficient when Armco Grain Storage Buildings are paired with modern materials handling equipment. Permanence is assured because Armco Buildings are all-steel—weathertight, rodent-proof, noncombustible.

Big-capacity 20-foot-high Armco Grain Storage Buildings or smaller multi-purpose Armco Buildings offer efficient flat grain storage. Armco Grain Bins—with capacities from 1000 bushels up—round out Armco's wide selection of grain storage structures. These buildings are versatile, economical components of grain processing, storage, and handling systems.

All feature Armco STEELOX® Panel construction. Benefits are high strength/weight ratio, precision fabrication, simple low-cost erection, and low maintenance. Write for details about this **BETTER WAY TO BUILD.**

FINANCING ARRANGEMENTS AVAILABLE

ARMCO STEEL BUILDINGS

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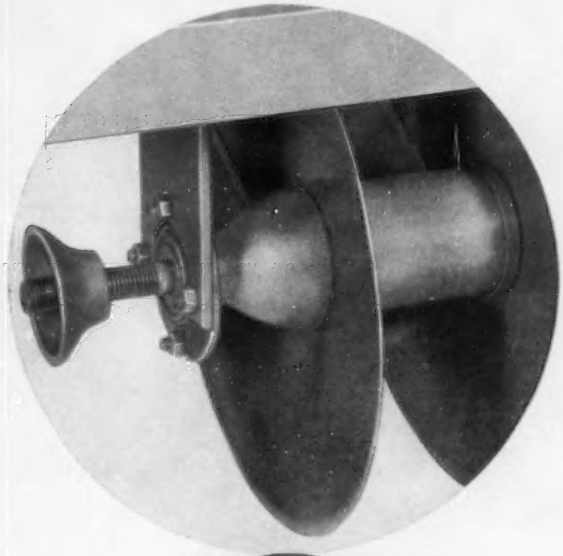
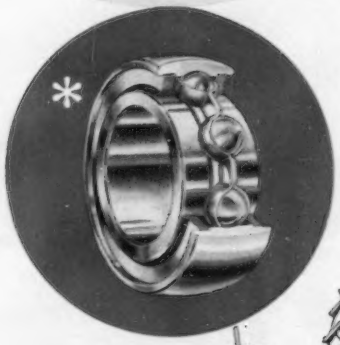
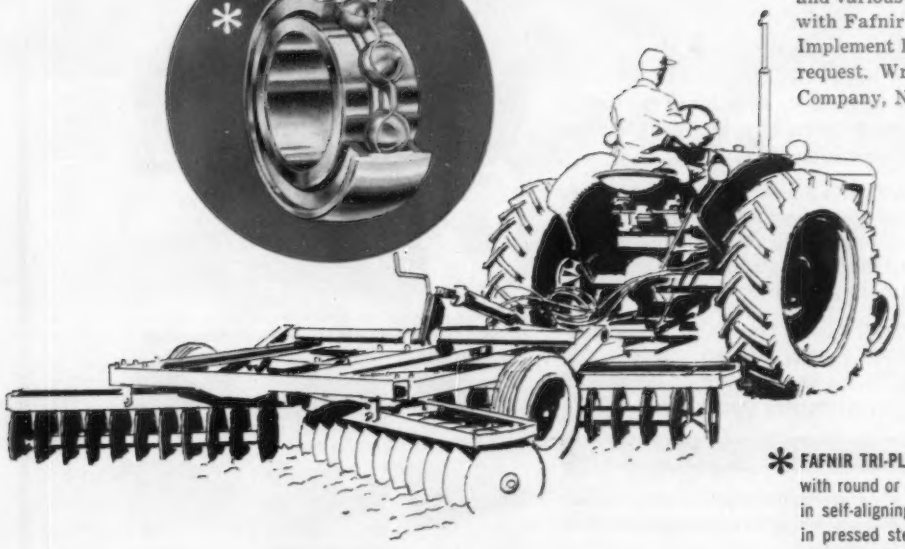
How to pull more harrow with the same "horses"!

Oliver equips for low-draft discing with maintenance-free Fafnir Tri-Ply-Seal Ball Bearings







Antifriction design featuring greased-for-life Fafnir Tri-Ply-Seal Ball Bearings packs plenty of "farmer-appeal" into Oliver 241 All-Purpose Disc Harrows!

This modern, semiflexible heavyweight digs deep, yet pulls with ease . . . makes it possible to use a larger size harrow without increasing horsepower.

Tri-Ply-Seals on every ball bearing lock out all damaging dust, dirt, and moisture and prevent loss of lubricant. Bearings never need greasing, thus dirt introduced by faulty relubrication practices is eliminated. Compact, self-contained Flangette bearing housings really increase trash clearance . . . give the Oliver 241 the slenderest standard and bearing assembly. Efficient, trouble-free design any way you look at it!

Bulletin containing detailed information, complete specifications, and various mountings possible with Fafnir Tri-Ply-Seal Disc Implement Bearings is available on request. Write The Fafnir Bearing Company, New Britain, Connecticut.

* **FAFNIR TRI-PLY-SEAL BALL BEARINGS** with round or square bores are available in self-aligning types for mounting in pressed steel Flangette bolt-on housings, or in cast iron housings. Rigid types for trunnioned, self-aligned housings with straight bores are also available.

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BALL BEARINGS
MOST COMPLETE LINE IN AMERICA

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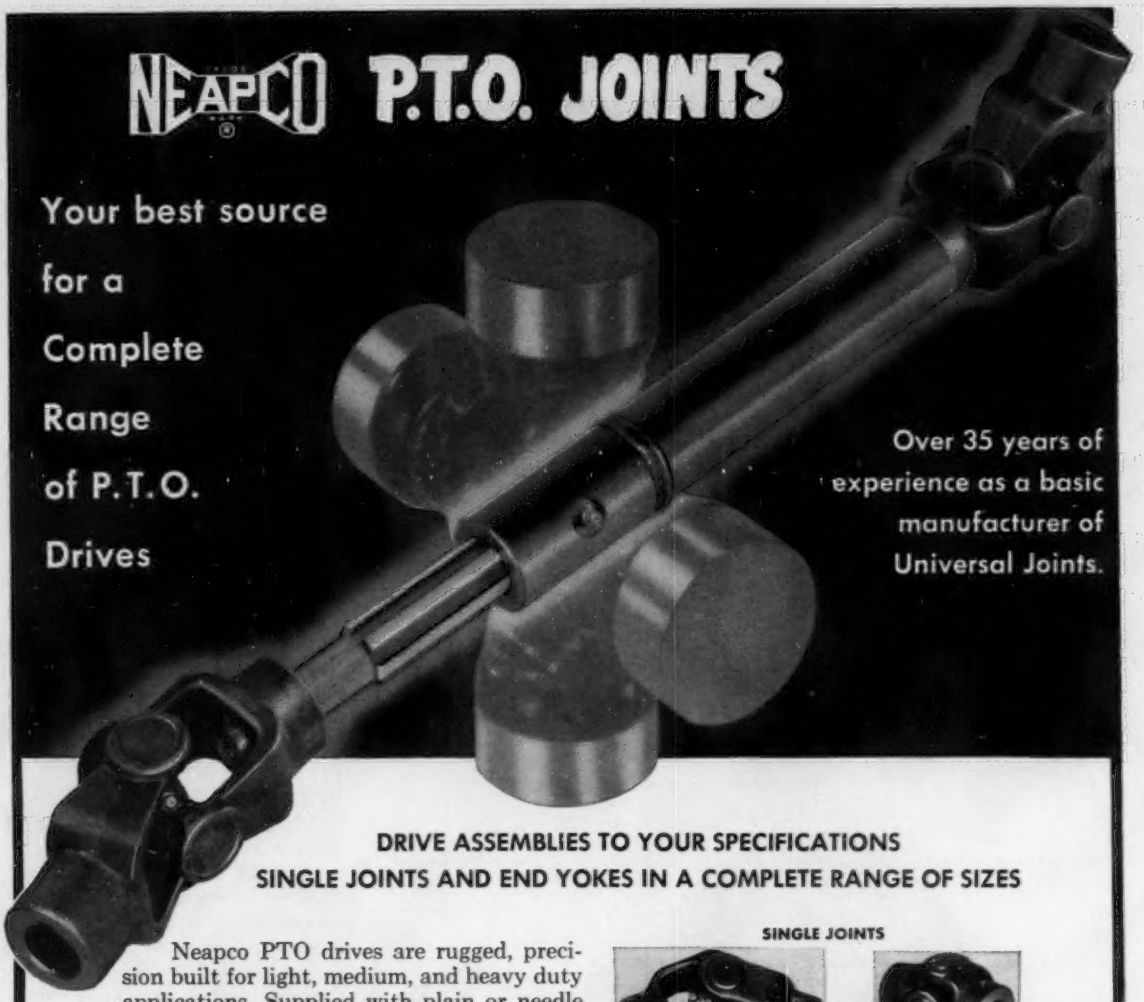

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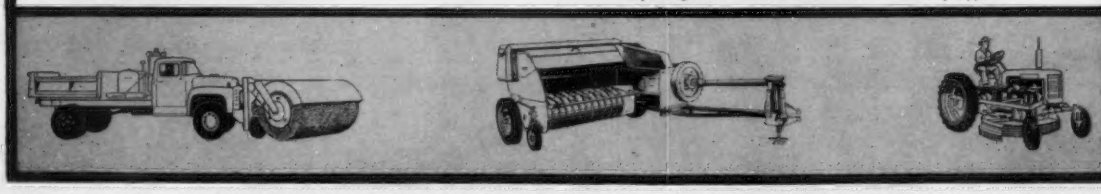

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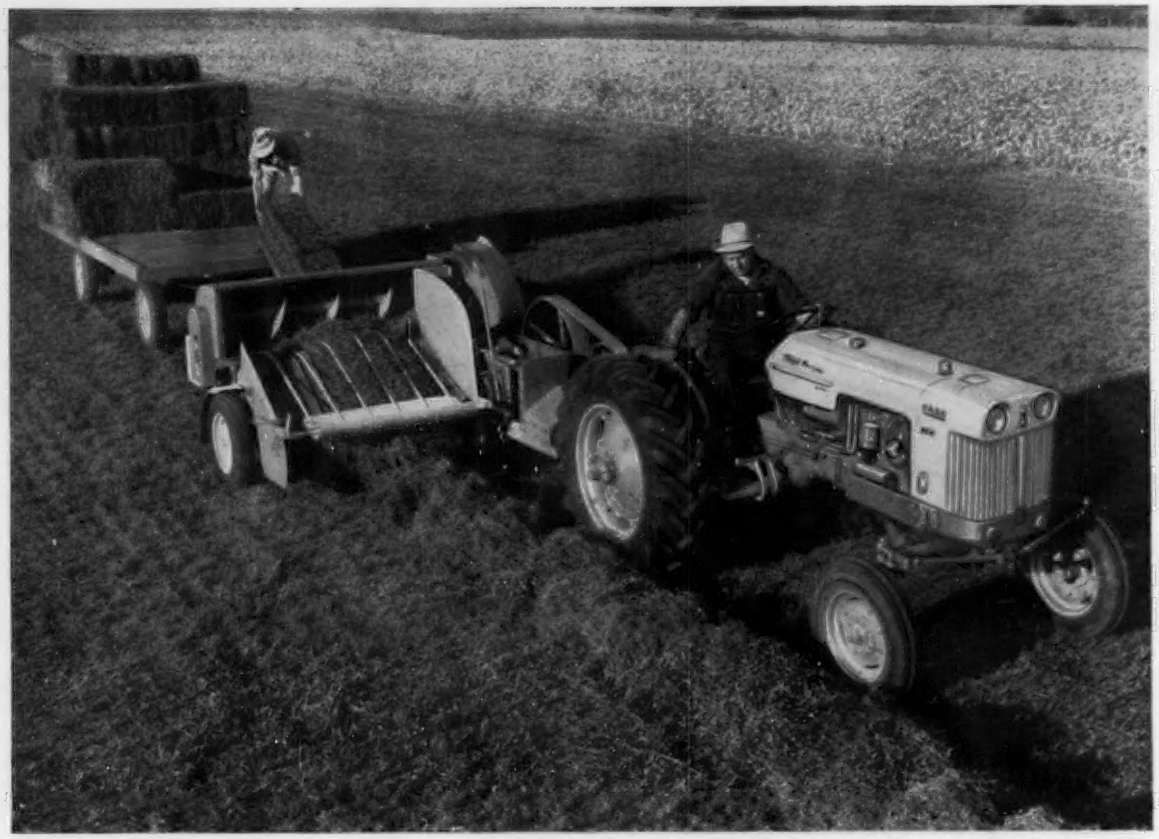

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Manhattan engineers are ready to help specify the proper belt for your needs and to work with you on the design of new power transmission drives. Let R/M show you why Manhattan Agricultural Belts can add "More Use per Dollar" to the equipment you manufacture.

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Agricultural Engineering

September, 1958
Number 9
Volume 39

James Basselman, *Editor*

Materials Handling: Farm Production Integrator

Guest Editorial by Harold E. Pinches, Fellow ASAE

HANDLING of materials is as old as agriculture. It is a natural and inevitable part of farm work. *Materials handling is any operation which changes the spatial location of the material,* without changing its form or composition except incidentally. What, then, is new or distinctive in the current interest in "farm materials handling," and in its potential economic and industrial importance?

Why has farm materials handling lagged behind relatively in development? It may be that materials handling has not so much lagged, in an absolute sense, as that it has now come to the fore as the next area needing and ready for development comparable to the earlier revolution in field machines and field practices.

Some characteristics and necessities of early agriculture put priority on invention and improvement of field machines. Field operations were limited in total time available in any season—often only a few days per year; a farmer's productive capacity was limited by what he could do in those few days. Tonnages to be handled in field work—whether of soil in tillage or of crops in harvest—made total human energetic demands per day excessive. Relatively uniform aspects of many field conditions permitted designing or inventing to meet requirements of soil or crop over wide areas. For example, wheat in Ohio is very similar to wheat in Kansas or California. In contrast, barns and farmsteads are nearly as individual as their owners.

Moreover, early farms were generally, of necessity, much more diversified and heterogeneous in activities than now— or will be in future. While diversification may have provided a degree of self-sufficiency and independence in relation to any given market or commodity price, it reduced the volume of each commodity handled; and it introduced diversities of products often incompatible for handling with similar equipment.

Diversification probably tended to make people "think small" —farmers and suppliers alike — since anything to be attractive in price and economically justifiable under the low use-factors imposed by diversification had to be "cheap."

Farm equipment use-factors will rise in the years immediately ahead through *(a)* growing sizes of farms bringing larger volumes of given commodities on larger farms, and *(b)* increasing relative concentration on fewer lines per farm. Hence, through specialization, the equipment needed, and the economically-justifiable capital input into any item of equipment, for such larger specialized activity may be many times greater than could have been afforded or justified on *the same acres* under earlier farming organization and practices.

EDITOR'S NOTE: Harold E. Pinches, Assistant to Administrator, Agricultural Research Service, U.S. Department of Agriculture, has demonstrated in published articles, in addresses before various groups, and in personal conversation his interest and keen sense of prognosis in foreseeing the progression of farmstead systematizing. In recognition of his leadership and advanced thinking in the field of management engineering in agriculture, the ASAE Committee for Conference on Materials Handling recommended that Mr. Pinches be invited to "set the stage" for this special issue in a guest editorial.

Farm materials handling may be regarded as little more than mechanization of particular existing operations, in order to save labor, reduce extreme energetic demands, or to save time for other operations, but without essential change in size or type of enterprise. That is, it is easy to develop something by invention for specific, localized tasks. That such step-by-step advances, even "gadgeteering," represent progress is not to be denied. We have come far enough, however, to ask of any proposed equipment or method whether it will result in more than patching up and perpetuating of the obsolescent.

Alternatively, research and development in materials handling may be guided and sustained by efforts to progressively eliminate those restrictions on the size of a man's enterprise, or productive capacity, which are determined by how much he can move, carry, or distribute in the working hours available to him. Every phase of materials handling should be regarded as a link in an integrated system of processes involving operations, transportation, and storage, with clear recognition that any link could be a constriction or limit on the efficiency or capacity of the whole system.

These are concepts of materials handling as, on the one hand, labor saving, reducing or eliminating time-consuming or onerous tasks; or, on the other hand, as the implementation of designs for the more efficient "flow of materials through the plant." The first, although worthy and eminently desirable, may be a piecemeal, episodic, non-integrated approach. The second, while often involving piecemeal installations and successive closer approximations of optimal conditions, will seek methods and equipment which will act together as parts fitting into and furthering an overall plan.

A manufacturing enterprise may be housed in a new factory building and be equipped with the most modern machine tools, yet be unprofitable for lack of properly coordinated work flow and flow of materials through the successive stages of manufacture. We are beginning to see that similar relationships apply in agriculture—both on the farm, and in the movement of farm products into channels of trade, fabrication, and utilization.

If farm materials handling is to advance as rapidly and economically as is possible, there will need to be successive and progressively more complete integrations of processing, materials handling, structures, sources of energy and power and means for their application, and of farm transportation. This will call for a type of production engineering, management engineering, or systems engineering to which all can contribute — rather than the more singleminded, but sometimes mutually exclusive, approaches of technical experts in limited fields or product-bound commercial representatives.

Materials handling can be a great new dynamic in agriculture; first, at the farmstead; then, by interaction and integration, over the whole farm, and beyond into marketing and utilization activities.

Handling Materials on Farms

George H. Seferovich
Affiliate ASAE

"My mission is to paint with a broad brush the framework in which engineers, economists, farm managers, and equipment production and marketing people must tackle the particular problems of handling materials on farms . . . the economic justification for dedicating more capital and effort to this area of agriculture and business, and some of the prerequisites for earning maximum results regardless of your particular occupation, association, or interest."— George H. Seferovich

THE title of this paper, "handling materials on farms," is purposeful. It is more inclusive than "farm materials handling." The former phrase includes handling off-farm produced supplies which farmers purchase for production. Examples include chemicals, commercial fertilizers and liming materials, petroleum products, minerals and other supplements used in animal rations.

In its broadest sense, the greatest part of a farmer's productive work involves materials handling. That means deliberately changing the location or the position of materials for storing, processing, utilizing, marketing and disposing of waste. The concept can be extended to include many field operations not usually associated with the term materials handling. But, because of practical limitations in introducing such a comprehensive subject, I shall place emphasis on the materials handling aspects of the post-harvesting operations.

Only recently has the magnitude of the materials handling tasks on farms been subject to study. Considering the volume and the weight of materials handled yearly on American farms, nothing deserves more serious interest. Some of the major tonnages are, in round numbers: hay, 100 million tons; corn, 100 million tons; milk, 60 million tons; commercial vegetables, 18 million tons; potatoes and sweet potatoes, 11 million tons; seed cotton, 10 million tons; eggs, 3 to 4 million tons; tobacco, 1 million tons (and this tobacco, of course, was several million tons heavier before drying)(1)*.

Farmers have struggled with weight lifting and unit load movement problems since the beginning of farming. Only recently have they tackled flow process problems. They have sought solutions in simple unit devices including block and tackle, hoists and hooks, and more recently, elevators, augers and a variety of tractor attachments. But now the problem of handling materials on farms goes far beyond tool invention and development and unit load movement. We are increasingly concerned with flow process which requires chaining together several components into a system. Our basic problem, to borrow the happy phrase of DeForest and his associates at *Successful Farming*, is to *make it a system*(14).

The tight labor market created by World War II stimulated the first serious attention to farm work elimination and simplification. During the years between the end of World War II and the end of the Korean War, farmers annually invested about $3.3 billion principally in improved general purpose tractors, field operating equipment, harvesting and haying machinery. That investment has paid off. It is estimated that three-fourths of the increase in production per man-hour between 1910 and 1957 has occurred since 1940. A large part of that increase must be attributed to both quality and quantity of field operating equipment. The spectacular increase in production per man-hour since 1910 of 421 percent for all food grains and 349 percent for all feed grains must be weighed against the meager 25 percent increase during the same period for meat animals. This disproportionate improvement in productivity focuses the spotlight on the farmstead, where post-harvesting operations and the feeding of and caring for livestock are centered. This is our target.

Farm operating efficiency and farm capital investment are not in ideal balance throughout the entire farm business. Until very recently most of us have been concerned with only one segment of the farm enterprise. In examining this subject of materials handling, let us employ a 3-D, broad screen, or vista vision approach. Let's assess *farming as a system* of integrated procedures to place materials handling in perspective.

Only by taking the management viewpoint can we fully appreciate the dimensions of this subject and proportion its several particular aspects. We should examine the problems arising from handling materials on farms for their engineering, economic, product development, production and marketing aspects. In such an assessment we must take the management engineering approach to farming as a series of interacting operations(1). We must investigate how to bring farming operations and farm capital investment into ideal balance. We must seek to eliminate work wherever possible. We must simplify and systematize tasks. Finally, we must integrate equipment into coordinated systems that reduce unit output cost.

The first premise of this conference must be that *farming is a business system.* As such, the *management-marketing-cost* aspects of farming must be emphasized as opposed to the *production-labor* aspects which have been receiving all of the attention. We have programmed our inventiveness and our sales effort to eliminate drudgery. We must now orient ourselves to reduce unit output cost by increasing the productivity of labor.

Handling materials on farms must be oriented to overall operating efficiency. Materials handling must be *implemented* for increasing labor productivity. It must be *integrated* into a system. And, it must be *capitalized* for the best return among the alternatives.

This, then, is a plea for looking beyond details of engineering principles and design problems and to focus attention on

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*Numbers in parentheses refer to the appended references.

the ultimate object of our effort, namely, the farmer who is today a capitalist and a manager and whom we must serve in those capacities if our efforts are to be fruitful.

The Cost of Handling Materials

When we view the farmer as a manager of labor time, we focus attention on man-hours required for farm production and the distribution of those man-hours among the several tasks (See Table 1). The mechanization of crop production,

TABLE 1. PROPORTION OF MAN-HOURS SPENT IN SELECTED CATEGORIES OF FARM WORK

Year	All-crops		Livestock		
	Preparation and pre-harvest	Harvest	All work	General farm maintenance	Total
1910	31	25	29	15	100
1920	31	25	29	15	100
1930	31	24	30	15	100
1940	26	25	34	15	100
1950	21	25	39	15	100
1955	20	25	40	15	100
1956	19	25	41	15	100
1957	19	24	42	15	100

Source: Agricultural Handbook No. 118, Major statistical series of the USDA, Vol. II, Agricultural Production and Efficiency.

the many factors that have increased yields and the more effective employment of effort have combined to bring about a startling increase in labor productivity associated with crop production. Thus, total man-hour requirements in agriculture have decreased from 22.5 million in 1910 to about 14 million today(3). Because efficiency in livestock production has not kept pace with efficiency in crop production (See Table 2).

TABLE 2. FARM PRODUCTION EFFICIENCY
Index Numbers of Farm Production Per Man-Hour
(1947-1949 average equals 100)

Year	Total farm output	All livestock	All crops	Meat animals	Hay and forage	Feed grains
1947-1949 average	100	100	100	100	100	100
1950	112	109	115	104	119	122
1951	113	114	112	106	125	131
1952	120	114	123	104	123	150
1953	123	116	124	104	124	155
1954	127	118	129	106	127	156
1955	132	121	135	108	126	162
1956	136	123	140	106	128	175

Data: Changes in farm production and efficiency, 1956 Summary, ARS 43-55, Agricultural Research Service, U.S. Department of Agriculture.

about the same number of man-hours is required now for livestock production as was required 40 years ago. Hence, we conclude that the typical farm worker spends a large proportion of his time in working with livestock than he does in crop production or in general farm maintenance work.

Before World War I, feeding and caring for livestock accounted for less than 30 percent of the work done on farms. This compares with almost 40 percent in recent years(4). In 1910, 55 percent of all farm work was spent on crop production, 30 percent on productive livestock and workstock, and 15 percent on general farm maintenance. By 1955, the labor for livestock had increased to 40 percent of the total, while labor for crop production had decreased to 45 percent of the total (12). Only in the production of milk, broilers and eggs has there been a significant breakthrough in the technological barrier in livestock production.

The urgency of reducing unit cost of production in red meats is one of the prime reasons for focusing attention on post-harvesting operations and on the farmstead. The farmstead is that area around structures used to condition, store and handle crops and to feed and care for livestock. It should be viewed as a processing center where farmers convert feeds and forage into meat, milk, or eggs. It is precisely in this work area where the efficiency gained in the field is dissipated. Here is just one small bit of convincing evidence: In 1955, more than 600,000 farms produced about 73 million tons of silage. Virtually the entire amount was field chopped mechanically with comparatively new, high-speed, large-capacity harvesters. Between 70 and 75 percent (51 to 55 million tons) was stored in upright silos. The fact that mechanical unloaders were used to remove only 4 percent (less than 3 million tons) of this impressive total indicates dramatically the present status of materials handling in the post-harvesting operations(6). This situation is also symbolic of the imbalance in capital investment.

When we view the farmer as a manager of capital, we focus attention on the amount and the proportion of capital invested in the various parts of his business and the relative return on each part. This area of farm management is a statistical desert. We have available only aggregate investment, or total capital invested by enterprise and by geographical location. We must rely largely on conjecture and on the questionable practice of generalizing on fragmentary evidence. Nevertheless, I have made some estimates of the proportion of capital invested for equipping various activities from farm accounts in Missouri and from analyzing the detailed information in the annual issues of USDA's *The Farm Income Situation* and in *Farmers' Expenditures*(10). It seems reasonable to place the proportions of total capital invested with a projection as shown in Table 3.

TABLE 3. THE CHANGING PATTERN OF FARM CAPITAL OUTLAYS
(Percent distribution by Major Categories)

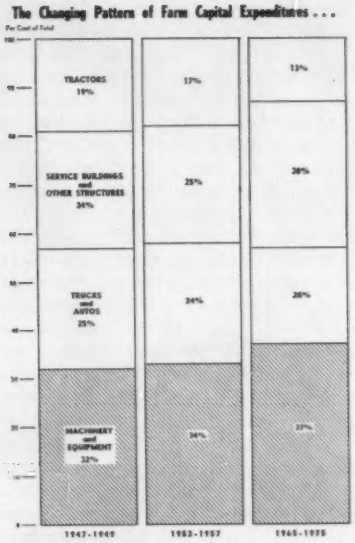
Category	1947 - 1949 (percent)	1953 - 1957 (percent)	1965 - 1975 (percent)
Tractors	19	17	13
Service buildings and structures	24	25	30
Trucks and automobiles	25	24	20
Machinery and equipment, total	32	34	37
Total	100	100	100

Source: Estimates based on data appearing in The farm income situation, FIS 164, Table 19, AMS USDA and The balance sheet of agriculture, ARS, USDA. Projections are author's.

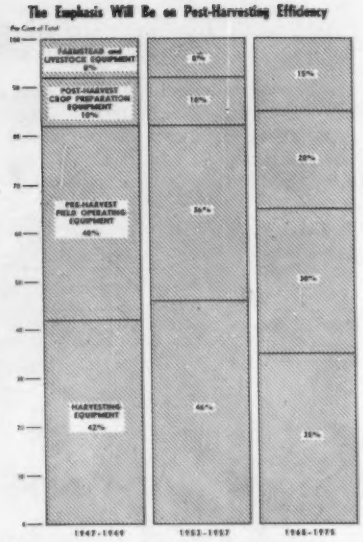
When to Mechanize?

The management view of handling materials precludes our considering only the equipment and the capital aspects. Mechanization is not always the most efficacious means of increasing the productivity of labor. Labor efficiency studies of cattle feeding operations disclose that on similarly equipped farms the most efficient operators handle feeds at six times the rate achieved by the least efficient operators(2, 12).

The management view compels us to examine the roadblocks and bottlenecks that keep returns to farm labor and management comparatively low. Handling materials must consider the design and the arrangement of buildings and structures as dictated by function and studies of work sequence. We must examine work habits by the time and motion study technique. Time and travel studies are currently cooperative projects of the USDA's Agricultural Research Service at several strategic locations.



Percent distribution of farm fixed capital investment is shown in Tables 3 and 3a. Fig. 1 *(left)* is a bar graph of Table 3 and Fig. 2 *(right)* is a bar graph of Table 3a. Fig. 2 treats the lowest part of the bars in Fig. 1 as though they were 100 percent. The purpose is to show the proportions invested in the Machinery and Equipment segment by functional category. See Tables 3 and 3a for sources of data



. . . Handling Materials

Van Arsdall suggests the following questions as a guide to knowing when to mechanize(12):

1 What is the initial cost of the equipment?
2 What is the annual cost of owning and operating the equipment?
3 What are the possibilities of making more effective use of existing facilities rather than purchasing new equipment?
4 How much labor will the equipment save?
5 What is the value of labor that would be replaced by the equipment?
6 What effect will the equipment have on the cost of other inputs, or on the quantity or quality of the products?
7 What effect will the equipment have on the organization of the farm business in terms of labor distribution, and size and type of enterprise?
8 Is the equipment suited only to one special purpose or will it be usable for several different operations and enterprises?
9 Will the new equipment contribute to an integrated system of production in view of existing and planned facilities?
10 What are the needs and possible returns of investing the initial cost of the equipment in some other part of the farm business or family living?
11 Will the added equipment contribute to making the business of farming an easier and more enjoyable occupation?

What units comprise farm materials handling equipment?

Equipment units designed primarily to lift, lower, stack, pull, push or otherwise deliberately change the position or the location of farm products, by-products, waste products or purchased materials constitute the generic class—*farm materials handling equipment.* It is helpful to distinguish between *unit load* devices and *continuous flow* devices. The former group are designed to handle materials in batches, one batch at a time. Tractor mounted loaders provide an example. The latter group are designed primarily to set materials into uninterrupted motion and direct the flow. Augers and chain elevators are examples.

With this as a practical definition, individual items can be isolated in the annual information collected by the Census Bureau from farm equipment manufacturers(9). Such a list is presented in Table 4.

How much materials handling equipment is in use?

The heterogenous units comprising this class of equipment prohibit precise summation. But, we are offered two methods for generalizing. First, an estimate can be made of the total investment in materials handling equipment in comparison with other categories of farm fixed capital investment. Also, annual purchases in dollar values for selected categories of equipment can be compared for cyclical behavior and trend. By a second method we can select representative units of equipment and then estimate annual purchases by farmers of such units to approximate the stock of such equipment in use at specified periods of time.

The first method, namely proportion invested, was used earlier to emphasize the growing importance of the post-harvesting operations in raising the level of farm labor efficiency (Refer to Tables 3 and 3a and to Figs. 1 and 2). The data suggested that about 6 percent of total farm fixed capital is now invested in materials handling equipment. That includes some investment in crop preparation units, such as dryers, which cannot be accurately separated from the total.

TABLE 3a. THE CHANGING PATTERN OF FARM CAPITAL OUTLAYS

(Percent Distribution of Machinery Category Only, see Table 3)

Functional Category	1947 - 1949 (percent)	1953 - 1957 (percent)	1965 - 1975 (percent)
Total machinery and equipment as percent of total capital investment	32	34	37
Components of total, taking machinery as 100 percent	100	100	100
Harvesting equipment	42	46	35
Pre-harvesting field operating equipment	40	36	30
Post-harvesting crop preparation equipment	10	10	20
Farmstead and livestock equipment	8	8	15

Source: Based on estimates by author from data in Farm machines and equipment, Facts for Industry, Series M35A, Bureau of the Census.

TABLE 4
FARM MATERIALS HANDLING EQUIPMENT
MANUFACTURERS' DOMESTIC SHIPMENTS

TYPE OF EQUIPMENT	1956		1955		1954		1953		1952		1951		1950	
	UNITS	VALUE $1000	UNITS	VALUE $1000	UNITS	VALUE $1000	UNITS	VALUE $1000	UNITS	VALUE $1000	UNITS	VALUE $1000	UNITS	VALUE $1000
Bunch or Unit Load														
Loaders, tractor mounted	39,565	11,882	39,632	10,859	47,648	13,965	63,842	13,520	81,177	17,022	68,802	17,169	43,095	9,842
Loaders, Hay Bale (field type)	3,616	763	4,508	997	5,339	1,181	9,593	1,959	4,622	998	2,310	501	3,850	727
Stackers, Hay	2,766	1,547	4,177	2,472	3,832	2,851	6,986	4,477	10,179	4,961	4,350	1,308	3,796	1,023
Feed Trucks (hand carts)	3,831	248	4,656	277	2,949	215	5,388	311	5,910	314	4,004	201	3,861	198
Feed & Litter Carriers (overhead rail)	1,993	117	2,742	153	2,981	175	2,825	159	3,979	205	5,985	286	4,359	199
Continuous Flow														
Silo Fillers	76	23	168	46	229	59	274	117	596	264	894	368	1,886	683
Silo Unloaders	2,581	2,022	1,524	1,368	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Poultry Feeders (Automatic)	7,384	3,548	4,761	2,134	3,615	2,111	4,029	2,232	4,438	2,350	5,690	3,018	4,194	1,570
Mechanical Feeders	3,908	224	3,329	125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pipe Line Milkers (Individual Cluster)	14,643	3,281	8,494	2,454	6,622	1,617	3,958	816	NA	NA	NA	NA	NA	NA
Barn Cleaners (Gutter Cleaners)	8,951	6,919	4,949	4,739	5,053	4,826	5,659	5,229	5,227	4,955	4,561	3,861	2,414	2,195
Elevators, Chain	57,607	13,644	66,501	19,140	NA	17,096*	66,583	18,963	69,056	19,632	70,674	20,019	77,293	19,775
Elevators, Auger	107,605	7,139	94,407	5,952	NA	6,506*	36,695	3,712	34,796	4,419	26,027	4,759	16,140	2,548
Blowers, Grain	113	35	169	83	8,210	2,476	237	378	391	232	561	221	2,952	454
Blowers, Forage	7,715	3,180	9,621	3,410			15,756	5,570	20,532	7,432	20,772	7,069	16,312	4,971
Other Types of Elevators and Blowers	2,384	1,059	2,554	1,805	NA	NA	2,124	352	2,089	408	320	95	271	194
Wagon Bed Unloaders	5,608	1,996	6,427	2,868	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTALS	269,566	57,827	258,629	56,382	87,708	53,878	214,852	57,787	232,992	63,192	214,950	58,875	179,523	44,379

* Total Value, Domestic Shipments not available separately

DATA: FARM MACHINES & EQUIPMENT, FACTS FOR INDUSTRY, BU. OF THE CENSUS, Series M 35-A

In Table 5 annual sales of farm equipment, as reflected by manufacturers' shipments, are presented. The dollar value of shipments for domestic farm use have been broken down into three major categories: farm equipment excluding tractors, wheel tractors for farm use, and materials handling equipment. A study of these figures reveals a steady growth in the percent of total sales accounted for by materials handling equipment. There is a marked growth trend from 3.7 percent of total sales for this classification to 6.4 percent between the years 1950 and 1956. In contrast the trend in tractor sales has not only been downward but erratic.

By this first method we are led to conclude that materials handling equipment on farms at the present time is insignificant in comparison with other classifications of farm fixed capital. However, there is clear evidence of a steady growth trend not marked by erratic fluctuations in sales characteristic of several other classifications of farm equipment, principally tractors.

The second method, by representative units, is more subjective because of items selected. Also, severe limits are imposed by inadequate statistical information. Nevertheless, taking elevators (chain and auger) as a symbol of materials handling and comparing their annual sales and the number in use with similar information for wheel-type farm tractors provides us with an *index of status*. These data are presented in Table 6. The data have been graphed and presented on a ratio scale to show rate of growth rather than absolute values (See Fig. 3). Thus, we can see more clearly the rapid growth in elevators, the symbol of materials handling, compared with the leveling off in tractor numbers, the symbol of field work efficiency.

What constitutes a measure of adequacy?

In the foregoing section it was suggested that the quantity of farm materials handling equipment currently in use is inadequate. That conclusion was arrived at by a comparison of investments in materials handling equipment with other categories of farm fixed capital. Also, comparisons were made in the annual sales of selected categories of equipment.

However, another attack is possible. We can examine into *effects* as opposed to *cause*. Reverting to our earlier objective of raising the level of farm work efficiency in the farmstead area, we can substantiate our contention that at the present time the quantity and the variety are inadequate. Furthermore, there is something short of optimum employment of farm materials handling equipment. Kleis(13) shows the percent of

TABLE 5
FARM EQUIPMENT SALES 1950-56
(MANUFACTURERS' DOMESTIC SHIPMENTS OF COMPLETE UNITS ONLY)

YEAR	TOTAL TRACTORS, FARM MACHINES AND EQUIPMENT			(1) EQUIPMENT EXCLUDING TRACTORS			(2) WHEEL TRACTORS			(3) MATERIALS HANDLING EQUIPMENT		
	THOUSANDS	% OF 1950-56 AVERAGE	% OF TOTAL	THOUSANDS	% OF 1950-56 AVERAGE	% OF TOTAL	THOUSANDS	% OF 1950-56 AVERAGE	% OF TOTAL	THOUSANDS	% OF 1950-56 AVERAGE	% OF TOTAL
1950	$1,202,179	103	100	$754,628	104	63	$447,751	106	37	$44,379 (4)	80	3.7
1951	1,479,285	129	100	911,686	126	62	567,599	134	38	58,575	105	4.0
1952	1,365,188	110	100	814,131	112	64	451,857	107	36	63,192	113	5.0
1953	1,168,661	102	100	722,755	99	62	445,906	106	38	57,787	104	4.9
1954	912,304	79	100	600,700	83	66	311,604	74	34	53,878	95	5.8
1955	1,104,919	96	100	672,712	93	61	432,207	102	39	56,382	101	5.1
1956	904,862	79	100	606,862	84	67	300,000	71	33	57,827	104	6.4
1950-56 AVG.	$1,148,474	100	--	$726,171	100	-	$422,303	100	-	$55,846	100	--

DATA: (1) Farm Machines and Equipment – Facts for Industry – Bureau of the Census.

(2) Tractors – Facts for Industry – Bureau of the Census.

(3) Table 4.

(4) Value of materials handling equipment shipments is included with "equipment excluding tractors."

. . . Handling Materials

farms on which operations are largely manual in handling hay, silage, other feeds and bedding. From his study of systems for handling materials on Michigan livestock farms, selected data are presented in Table 7. With few exceptions, distributing materials in storage, removing them from storage and utilizing them are largely manual operations on more than 80 percent of the farms studied.

A suggestion of inadequacy is also implied in the section dealing with the economics of handling materials on farms which called attention to farm production efficiency in crop output as compared with livestock output.

How effectively is it being employed?

No evidence can be presented at this time on the effectiveness of employment of materials handling equipment on farms. First, a conclusion would only be warranted after representative studies of employment of such equipment on farms. More importantly, there would likely be a substantial discrepancy between the theoretical work capacity of components and the effectiveness of employing the components as an operating system. For example, studies at several of our land-grant colleges, principally Nebraska and Texas, point to the comparatively low level of total operating efficiency of irrigation systems in which efficient components are integrated into an inefficient complete system. I have been unable to locate studies of equal objectivity devoted to effective employment of components in a materials handling system.

TABLE 6. TRACTORS ON FARMS COMPARED WITH ELEVATORS ON FARMS

(Figures are Units)

Year	Wheel-type farm tractors* Annual sales†	Wheel-type farm tractors* Farm inventory‡	Portable, power elevators Annual sales§	Portable, power elevators Farm inventory‖
1940	215,701	1,545,000	8,100	90,000
1941	286,858	1,665,000	11,500	98,000
1942	161,668	1,860,000	7,800	109,400
1943	82,576	2,055,000	11,600	116,500
1944	205,897	2,160,000	16,300	128,000
1945	186,281	2,354,000	21,700	144,000
1946	206,951	2,480,000	36,100	165,000
1947	352,433	2,613,000	42,700	200,000
1948	436,984	2,821,000	72,700	240,000
1949	445,030	3,123,000	83,900	310,000
1950	425,815	3,399,000	93,433	390,000
1951	472,821	3,678,000	96,701	480,000
1952	360,366	3,907,000	93,952	567,000
1953	336,401	4,100,000	93,278	651,600
1954	212,832	4,243,000	162,300	730,600
1955	284,690	4,345,000	160,908	868,600
1956	170,953	4,450,000	165,412	1,000,000
1957	181,247	4,560,000(#)		1,130,000

Data:

*Farm inventory figures include all tractors on farms exclusive of steam and garden. Annual sales are for wheel-type farm tractors only.

§Manufacturers' shipments for domestic farm use, annual Facts For For Industry, Tractors, Series M37A, Bureau of Census.

‡Stock on farms Jan. 1, *Power and Machinery on Farms*, ARS 43-26.

§Manufacturer's shipments for domestic farm use, annual Facts For Industry, Farm Machines and Equipment, Series M35A, Bureau of the Census.

‖Farm Power and Farm Machines, FM 101, Bureau of Agr. Econ., USDA and author's estimates for years since 1951.

(#)Author's estimate.

What work requirements remain in need of principles application?

We get our best index of mechanization possibilities from analyzing man-hours requirements studies augmented by farm case histories and time and travel studies. They all point to feed preparation and feeding as offering the greatest mechanization potential. As pointed out earlier, only 4 percent of the 1955 silage crop was removed from vertical silos mechanically(6). Fewer than 13 percent of the livestock farms in Michigan in 1955 removed hay from storage mechanically(13). These two citations indicate the general inefficiency in the handling of hay, forage and feeds.

Observation suggests other areas for attention but no statistical evidence can be presented. For example, the storage and handling of chemicals, including commercial fertilizer, is largely a manual operation.

In the disposal of farm waste materials, farmers seem to be efficient only in the handling and disposition of manure.

We hope that the cooperative studies under the auspices of the Livestock Engineering and Farm Structures Research Branch, Agricultural Engineering Research Div., Agricultural Research Service of the USDA, and the studies in progress at the Agricultural Work Simplification Laboratory, Agricultural Experiment Station, Purdue University, Lafayette, Ind., will generate the type of research information which can direct the most effective product development for farm sales opportunities.

Market Prospects

Evidence was presented in the preceding section to appraise the status of handling materials on farms. The data describe an immature market. Engineering and sales opportunities abound. In assessing this potential let us not lose sight of our ultimate objective—to increase the productivity of farm labor in the post-harvesting operations and in the output of livestock products. In pursuing this objective we must retain the management viewpoint to appreciate the totality of farm work simplification and farm cost reduction problems. Immediate

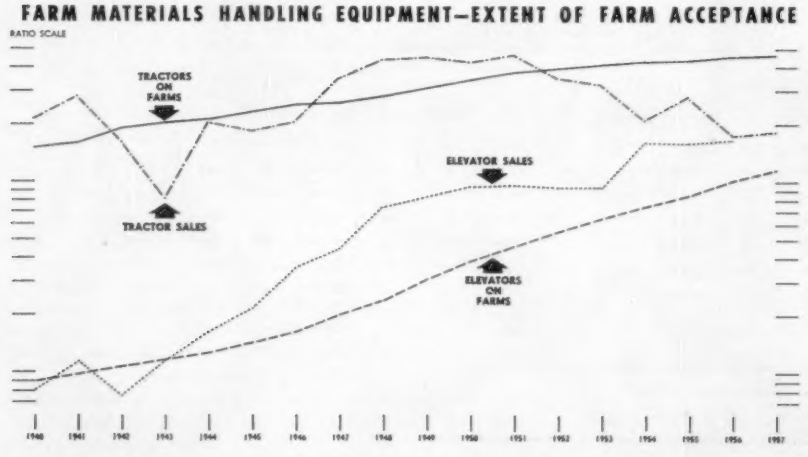


Fig. 3 Data in Table 6 are plotted in this graph on a ratio scale to show rate of growth instead of amounts of equipment. There are roughly four times as many tractors on farms as there are elevators. But, using elevators as a symbol of materials handling equipment, and tractors as a symbol of field operating equipment, the relative change in the two categories can be dramatically compared in this manner

TABLE 7. PERCENT OF FARMS ON WHICH OPERATIONS ARE MANUAL

Operation	Hay			Silage		Bedding			
	Baled	Chopped	Long loose	Vertical silo	Horizontal silo	Baled	Chopped	Long loose	Other materials
Unloading from vehicle	10	0	8	4	0	13	4	60	42
Distribution in storage	82	21	100	28	17	85	28	30	33
Removal from storage	98	87	100	89	30	100	97	100	83
Moving to utilization area	44	29	46	41	12	52	39	30	33
Utilization	87	72	100	90	29	100	100	100	92

Operation	Ear corn	Small grains	Concentrates	Operation	Ground feed			
					Dairy	Beef	Poultry	General livestock
Unloading from vehicle	20	19	88	Grinding and blending	0	0	0	0
Distribution in storage	12	13	41	Moving to feeding area	64	33	0	64
Removal from storage	76	60	86	Feeding	93	100	62	94

Source: Kleis, R. W., An analysis of systems and equipment for handling materials on Michigan livestock farms unpublished Ph.D. thesis, Michigan State Univ., 1957.

goals provoke us to emphasize materials handling and more specifically materials handling *equipment.*

To accomplish the ultimate job of winning farmer acceptance will require much teamwork. This whole area of farm work simplification and farm cost reduction cuts across several technical and commercial specialties including engineering, economics and selling. I fully appreciate the interdependence of such information and activity. Nevertheless, I am inclined to believe from the evidence presented on the present status of materials handling, that our first task is to overhaul our marketing organizations and selling methods.

The market requirements for farm materials handling equipment demand a different type of selling personality, a different type of retail organization, and a different sales approach to the farmer. The farm equipment industry faces a different job in raising the level of productivity in post-harvesting operations than it did in increasing productivity in field work and crop production. The emphasis is shifting from *implementing* to *construction-engineering.* Concurrent with this essential change in design and production requirements, an equally substantial change is taking place in marketing requirements. At the retail level, there is already some evidence of success with the techniques of application engineering as opposed to more traditional methods of merchandising.

In comparison with the selling of tractors, tillage tools and harvesting machinery, marketing farm materials handling equipment demands a different approach because:

The Selling Environment Is Different

Statistical evidence has already been presented to document the case for farmers being currently fairly well equipped to enjoy high productivity in crop output and field work. The shift in emphasis to the farmstead, to post-harvesting operations, and to the activities related to the output of livestock products is putting new significance on the economics of barnyard engineering. We do not have adequate information on this field in the hands of our marketing people, principally the retail salesman. Also, the emergence of large scale specialized enterprises producing livestock products means our marketing people, especially retail salesmen, are confronted with a new type of buyer. His decision-making process is similar to that of his counterpart in manufacturing enterprises. Briefly, this delineates the new selling environment in which construction and engineering are more in demand than tooling and powering, and in which application engineering and management economics are more effective than merchandising.

The Sales Approach Is Different

There is an urgent need and a rewarding opportunity for dynamic initiatives in selling farm equipment. Critical examination of traditional methods and policies will disclose some reasons why farmers are not adopting proved practices in work simplification and materials handling at a faster rate.

As a general rule farm equipment dealers have not taken the "management" view of farming. Their role has been that of a supplier. They have entered the decision-making process and the adoption process at the demonstration level rather than at earlier stages. A sales engineering approach must be taken. This is a method which employs factual data to explore alternative solutions to farm production problems and to decide which solution offers the greatest net return to the farmer. Thus there are three elements embodied in this method: *(a)* awareness of alternative solutions within the general framework of the farming system, *(b)* existence of quantitative data, principally economic in character, and *(c)* a way of treating and processing the data to produce reliable answers.

Also, essential to this method is the continuous recognition on the part of the retail dealer of the overall objective of the farm enterprise and the consideration of the system in its total aspects. That attitude and viewpoint are opposed to the fractional or piecemeal approach of selling one machine in isolation and thus ignoring the total process into which it must fit or be integrated with the least economic friction.

To cite just on example, Kleis presents a mathematical demonstration of the effect of additional investments in materials handling equipment on total farm labor required(13). It is information of this nature which must become part of the sales literature in this field. Most sales literature and dealer information consist of product descriptions, engineering and design features and similar physical characteristics of an individual machine. With a few notable exceptions, sales literature does not assist a farmer or the farm equipment dealer to integrate units into the farming system. Neither does most sales literature present the economic benefits of particular machines. For instance, the theoretical capacity of a piece of field equipment is presented as an argument for purchasing a certain size. The dealer in his sales presentation gives little recognition to the actual field operating capacity of that particular unit in conjunction with, very likely, mismatched transportation equipment, for example.

This is not the appropriate place for a full discussion of new approaches to selling farmers equipment. My purpose is merely to call attention to what I believe are the general requirements of the new market and some observed deficiencies. There is some evidence to suggest that the difficulties of selling complete systems, coupled with the low volume in limited retail sales territories, have tended to retard the development of aggressive sales programs of the order called for.

I want to emphasize that the new type of businessman-farmer, with serious problems of operating efficiency in his post-harvesting work, is demanding a type of consultative selling not generally employed in merchandising tractors, tillage tools and harvesting machinery.

The Equipment Is Different

Unlike standard farm equipment for field work, referred to

(Continued on page 537)

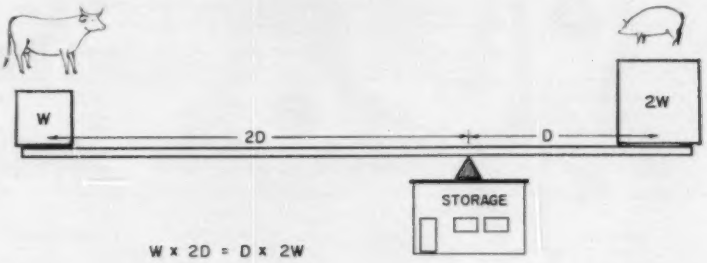


Fig. 1 Center of moments method of locating storage

Theoretical Considerations in Materials Handling Systems

Carl W. Hall
Member ASAE

How to move materials efficiently is not a new problem. But now new mathematical approaches promise some fresh, workable solutions.

THE ability of the people to handle materials is one of the major factors in the development of civilizations. Piping water for irrigation in early Babylonia, transporting stones for the great pyramids of Egypt, carting food and supplies across Europe by Napoleon, and moving the necessary supplies during World War I and World War II are materials handling problems familiar to all of us.

Materials handling includes labor, methods, equipment, and management. It is appropriate that these discussions have begun with a discussion of materials handling systems—equipment alone cannot comprise materials handling.

Materials handling systems have not developed as rapidly for agriculture as for other industries. Some industrial methods can be applied to agriculture, although this is not a simple procedure. Most industrial analysis is based on the relationship of man to machine operations. More variables—man, machine, animal, animal products, seasons — are involved in agricultural studies.

Basic Handling Methods

The first concern in classifying, studying, or selecting a handling component or system is the material involved. This approach is in line with our observation that materials handling is not a study of equipment only. The planning committee of this conference showed foresight when it set up the discussion categories based on materials as *(a)* liquid, *(b)* free-flowing, and *(c)* non free-flowing. Some of the same handling systems may be used for two or three categories of handling. Thus, bulk handling techniques can be used for liquid or free-flowing materials; pallet handling can be used for all categories.

The order of convenience of handling (but not necessarily in economical order) are liquids, free-flowing materials, and then non free-flowing materials. By changing the physical form, as pelletizing hay or grinding corn cobs, a non free-flowing material can be made relatively free-flowing. Or by suspending solids in water, a non free-flowing or free-flowing material can be treated as a liquid. Feeding a pump, transporting through piping, and depositing or storing a liquid material, such as liquid fertilizer, is simpler than handling non free-flowing or free-flowing materials such as solid fertilizers. Of course, free-flowing solids are only free-flowing to a certain extent, as determined by the angle of repose. (The angle of repose of water is 0 deg and of grains about 30 deg.) With liquids there is no problem of bridging nor is there a loss of the storage space necessary to provide the angle of repose needed for removing a free-flowing solid.

An estimate of the cost of a handling system could conceivably include the following: *(a)* fixed costs — machinery, structure, insurance, interest, and taxes; *(b)* operating costs—labor, energy, repairs, supervision, damage to the product, less increased returns through improvement in the quality of product.

Critical speeds of various materials handling components are often determined by the amount of damage sustained by the product handled. For each ton per hour, for each one percent damage, evaluated at $1.00 per cwt, the value of damaged product is 20¢ per hr. For handling eggs, how much additional breaking can be justified when replacing hand with mechanical methods? Consider also that the broken products —in this case, eggs—may not be a complete loss. In some cases the product damaged as a result of handling might have the same value as the undamaged product. During certain seasons of the year broken eggs are worth as much as unbroken eggs, for example.

Storage Location

Storage units should be placed where the materials can be handled at the least cost. Factors to be considered include the amount of material to be handled, distance to location of usage, and method of handling to points of usage. The *center of moments* or *center of gravity* method has often been used to locate storage units (Fig. 1). However, this method often gives an erroneous and misleading result. The simplest example is an arrangement for supplying materials to two places of consumption.

Assume that 500 lb are to be used at point A and 1000 lb at point B which is 300 ft away. Figuring the center of gravity,

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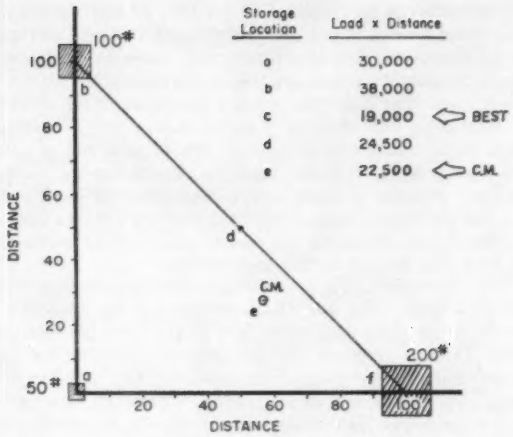

Fig. 2 Storage location for three feed areas

the storage would be located 200 ft from point A and 100 ft from point B. Thus, the load×distance would be 500×200 plus 1000×100 or 200,000 lb-load×ft-distance. But by placing the storage at point B, the load×distance is 500×300 or only 150,000 lb-load×ft-distance. If the cost of moving per lb-load×ft-distance is the same for two demand or usage locations, the storage should be located at the point of greatest demand. The greater the variation in amounts needed at the two locations, the more accurate the center of moments method becomes. If the cost of handling per unit weight is different for moving to A and B, locate the storage at the point of largest weight×distance×cost per (weight×distance).

A similar approach can be used where there are more than two feeding or demand locations. With three feeding locations as shown in Fig. 2, the load×distance is 18 percent less with the storage at the feeding area of maximum need, c, rather than at the center of moments, e. Generalizing, locate two or more feeding areas, W_1, W_2 and W_n at x_1y_1, x_2y_2, and x_ny_n (Fig. 3). The objective is to locate the storage, at (xy), where the weight times distance is a minimum, not at the center of moments. The distances from the storage to feed areas are d_1, d_2, d_n, where d_n is equal to

$$d_n=(x_n-x)^2+(y_n-y)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad [1]$$

and $d_1W_1+d_2W_2+\ldots d_nW_n \quad . \quad . \quad . \quad . \quad . \quad . \quad [2]$

must be a minimum. The first derivative, equal to zero, is solved for x and y to provide minimum values(13)*. Because of the complicated possibilities, selecting minimum values for x and y is easiest by trial and error. Possible sites of the storage should be selected, and (starting at the location of highest demand) the total weight×distance determined for various sites.

Capacity vs Cost of Operation

The total cost of operation of several systems can be determined for different volumes of flow. Total system cost can be a criteria for selecting a particular system. Total cost of operation is made up of fixed and operating costs. The fixed costs include those expenses which are incurred regardless of the time of operation. These include depreciation, interest, rent, taxes, insurance, and repairs, all of which might add up to an annual cost of 15 to 25 percent or more of the original cost. Often a much higher rate of write-off is desired, 2 or 3 yrs, and the fixed costs can be assigned accordingly.

*Numbers in parentheses refer to the appended references.

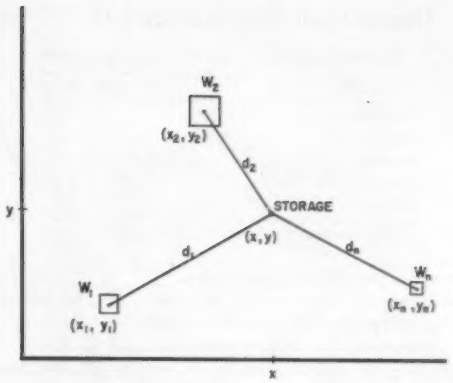

Fig. 3 Theoretical analysis of handling from storage to feeding areas

The operating cost, which may increase as the time of operation increases, includes labor, fuel, electricity, water, etc. The operating cost will often vary linearly with time, although it does not necessarily increase linearly with the time of operation, particularly if clean-up or preparation time is required at the beginning or end of the run. This time may be distributed over all of the volume handled for the period. In some operations the full time of a man may not be used until a certain capacity is attained. The energy cost may decrease per unit as the number of units is increased. Labor may increase if overtime is to be paid. Maintenance costs may not be linear.

A plot of the cost per unit weight or volume will show the optimum size of operation from the standpoint of cost. Various reasonable combinations of components can be made and costs determined (Fig. 4). Each possibility of combining components into a system can be listed. Total cost and increased return can be determined, and the system selected that will give the greatest net income. Net income from any product equals the quantity of product times the difference in selling price and the cost of production, namely, $I=Q(S-C)$. An excellent equation for determining the break-even point for a materials handling system is presented by Apple(1).

Some operations, such as barn cleaning, can be analyzed quite simply on the basis of time saved by different methods, costs involved, labor needed, etc.

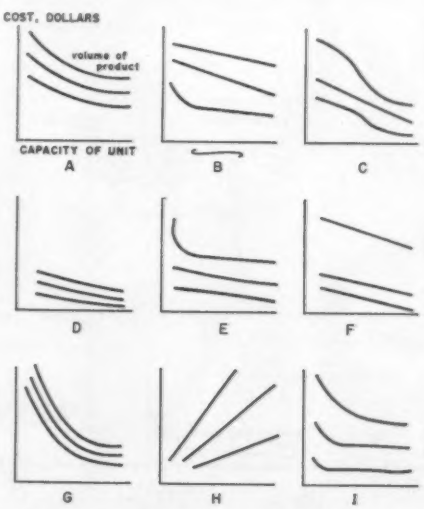

Fig. 4 Combine operations in most economical manner

. . . Theoretical Considerations

TABLE 1. BARN CLEANING BY VARIOUS METHODS (18)

Method*	Man-min per cow for 1 day
Wheelbarrow	1.16
Litter carrier	0.93
Spreader	0.92
Semi-automatic	0.48
Automatic	0.16

*For cleaning once per day. Based on 30-cow herd.

Investment in Handling Equipment

The saving in labor cost or time can be used as a basis for justifying investment in materials handling equipment. The greater the saving, the greater the investment justified.

The saving or reduction of labor from greater mechanization must be carefully evaluated. If the change reduces the labor requirement by 10 percent, but that time is not productively utilized, the expected saving is not attained. A change in the system should result in a reduction of hired labor by integral units, (1, 2, 3). (There is little difference in the total cost for a one-man operation, even though the work capacity of the man is not fully utilized (See Fig. 5). As the investment in labor is increased, the need for materials handling equipment is reduced (Fig. 6), or vice-versa. If the investment in materials handling equipment is doubled from $4000 to $8000, an average reduction of labor of about 42 percent can be expected(11).

Relate Components into a System

A simple method is needed to relate various components into a materials handling system to determine the most economical arrangement. It is doubtful that an evaluation method can be found to fit all problems encountered. The methods presented here unfortunately are not simple enough to use generally. As more information is obtained on the farm, data will be obtained to fit the equations or techniques presented, and assumptions can be made to simplify techniques presented. Detailed procedures for using and applying the methods presented are not given here, but references are listed to provide this source of information.

Flow Chart

A flow chart can be used to illustrate the movement of materials in a system. An existing arrangement and proposed arrangements can be evaluated on the basis of such factors as cost, returns, time, layout, flexibility, equipment and storage. An analysis of the flow of animals, feed, water, products, and man is available for beef and swine operations(10).

Let's see what handling system a farmer needs for feeding 20 dairy cows, 100 chickens, 3 litters of pigs, and 8 head of young cattle. Sixty tons of corn, 40 tons of oats, and 20 tons of concentrates are required annually. The following restrictions are imposed: grinding and mixing capacities must provide sufficient feed during a two-hour period every two weeks, equipment costs should be low, and all grain will be grown on the farm and will be custom harvested.

The flow chart, Fig. 7, shows the present handling and storage scheme. The flow chart permits a rapid analysis of amount of handling and shows how to eliminate unnecessary steps. Table 2 gives *(a)* the handling requirements for the system, and *(b)* the storage requirements. The handling requirements are listed: time of feeding, volumes of flow from place to place per hour or day or year, time of handling, and condition of material.

Weak points can be located by referring to the flow chart. Conveyors may be improperly sized. The grinder may not be used to capacity because of a slow elevating process. The mixer may be improperly sized. Solutions can be obtained after analyzing the present arrangement, questioning the necessity of each step, trying alternative combinations, and evaluating possible changes. Applications to industrial and agricultural problems are available(1, 5, 10).

Operations Research

Two different terms have been associated with the techniques to be presented: *Operations research*(4)—"the tentative working definition is the application of scientific methods, techniques, and tools to problems involving the operation of a system so as to provide those in control of the system with optimum solutions to the problems." What could be closer to a study of materials handling systems? *Systems engineering and systems analysis*(4)—"the application of science to the design of mechanical and man-made systems (not including social and human components)."

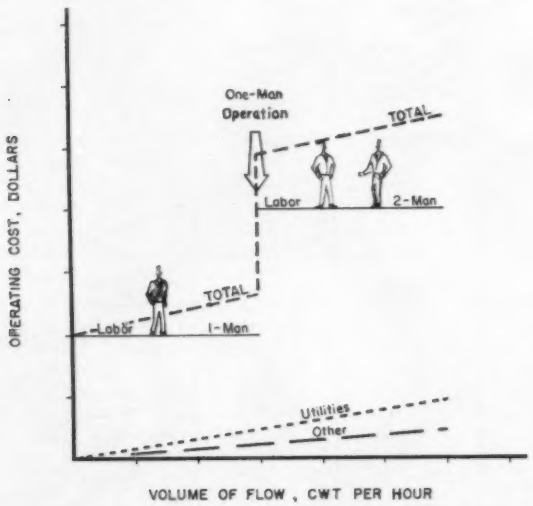

Fig. 5 Operate at an optimum rate for number of men

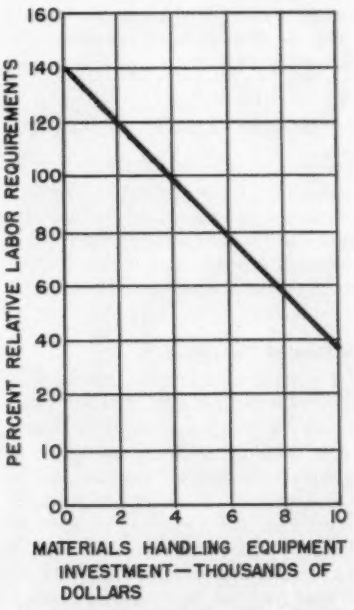

Fig. 6 Effect of investment in materials handling equipment on total labor

TABLE 2. FEEDING SYSTEM DATA (to accompany Fig. 7)

(a) *Handling Requirements*

No.	Material	Condition	Flow rate	Yearly rate	Time of handling	Remarks
1	Corn	Shelled	10 T/hr	60T	Once a year	Some on ear
2	Corn	Shelled	1.2 T/hr	60T	Every 2 weeks	
3	Oats	Dry	1.0 T/hr	50T	Once a year	
4	Oats	Dry	1.0 T/hr	40T	Every 2 weeks	
5	Concentrate	Dry	5 T/3 mon	20T	Four times per year	
6	Concentrate	Dry	0.5 T/hr	20T	Every 2 weeks	
7	Corn and oats	Ground	2.5 T/hr	100T	Every 2 weeks	Ground oats and corn to grinder
8	Ground feed	Mixed	3.0 T/hr	120T	Every 2 weeks	
9	Ground feed	Mixed	0.025 T/hr	40T	Twice daily	Feed cows in 15 min
10	Ground feed	Mixed	0.10 T/hr	8T	Daily	Feed stock
11	Ground feed	Mixed	3 T/hr	27T	Every 2 weeks	Feed pigs in 20 min
12	Ground feed	Mixed	0.125 T/hr	3.5T	Daily	Feed chickens in 5 min

(b) *Storage Requirements*

No.	Material	Condition	No. of inputs	No. of removals	Capacity	Remarks
1	Shelled corn	Dry	One per year	26 per year	2500 bu	
3	Oats	Dry	One per year	26 per year	2500 bu	
4	Oats	Dry	Three times in 2 weeks	Three every 2 weeks	1000 lb	
5	Concentrate	Dry	Four times per year	26 per year	5 T	
8	Ground feed	Mixed	Once per 2 weeks	Two times per day	2 T	
12	Ground feed	Mixed	Once per 2 weeks	Once daily	1 T	

Operations research is a procedure for helping management make proper decisions. Application of rigorous methods of analysis to an entire system, rather than to just one operation to obtain an optimum solution, might be called operations research or systems engineering. Operations research, pioneered by the British, has been used extensively by government and industry during and since World War II. Operations research has been used for determining *(a)* load and flight patterns during the Berlin airlift after World War II, *(b)* quantity and variety of products to be merchandized, *(c)* warehouse and building placement, *(d)* size of flight for bombing missions during World War II, *(e)* machine replacement, *(f)* cropping programs.

A large vegetable crop producing farm on the East coast, using operations research, found the most economical time to harvest to obtain maximum returns. As a result of the studies, a device was developed to aid management in making decisions regarding harvest(23). In surface mining operations, recommendations developed by operations research resulted in an increase of nearly 70 percent in operating efficiency(23). These examples are directly applicable to agricultural engineering.

Operations research or systems engineering is usually carried out as follows: *(a)* set up the problem, *(b)* make a mathematical model, *(c)* derive solution from model, *(d)* test model, *(e)* set up controls, *(f)* put solution to use.

After the problem is established, the major task is establishing and evaluating mathematically the many possibilities. Engineers should be particularly well qualified to apply these relationships in the form of mathematical models which represent in part the actual situation. The results obtained must be applied wisely. Symbolic models are developed using mathematical terminology. Various numbers are substituted in the model to obtain the optimum value. By trial and error, called *iteration,* we obtain a solution or solutions which give an optimum solution. There may be several feasible or even several acceptable solutions.

Mathematical Programming

Linear programming is the most used mathematical technique developed for relating and evaluating the relationship of variables. A typical problem in linear programming will have more unknowns than equations. The unknowns or variables are restricted to positive values. There is some value for which the objective is to minimize or maximize. It is implied that the relationship is linear—that is, it costs twice as much to handle two times the amount of material. One must be sure that the variables are linear. The two most important techniques of linear programming are the transportation technique and the simplex technique. Possibilities of applying these to agricultural materials handling will be emphasized.

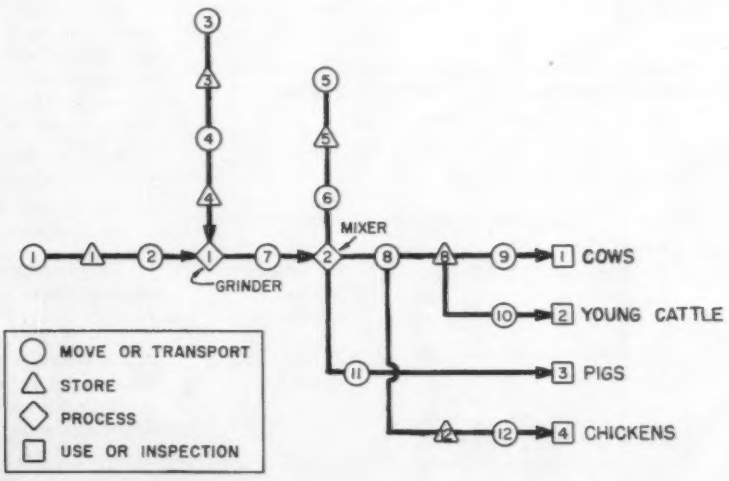

Fig. 7 Flow chart of handling system

. . . Theoretical Considerations

The transportation technique. The problem involves moving materials from surplus areas to deficit areas at a minimum cost. This is sometimes called the distribution method.

Assume that corn is available at three different locations, *m:* 1, 2, 3, and is needed at four locations, *n:* 1, 2, 3, 4, perhaps for poultry, cattle, hogs, and beef. The distribution matrix is represented by Table 3.

TABLE 3. MATRIX WITH QUANTITY AND COST

FROM \ TO	1	2	3	n	SUPPLY
1	c_{11} x_{11}	c_{12} x_{12}	c_{13} x_{13}	c_{1n} x_{1n}	S_1
2	c_{21} x_{21}	c_{22} x_{22}	c_{23} x_{23}	c_{2n} x_{2n}	S_2
m	c_{m1} x_{m1}	c_{m2} x_{m2}	c_{m3} x_{m3}	c_{mn} x_{mn}	S_m
DEMAND	D_1	D_2	D_3	D_n	$\Sigma D = \Sigma S$

The cost of moving the product is to be minimized. Thus:

x_{ij}=number of products moved from i the source to jth consumption.

$i=(1, 2, 3, \ldots m)$ at source

$j=(1, 2, 3, 4, \ldots n)$ at consumption

c_{ij}=cost per unit to move from ith source to jth consumption.

$$\sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}\, x_{ij} = minimum \quad . \quad . \quad . \quad . \quad . \quad . \quad [3]$$

TABLE 4. FIRST FEASIBLE SOLUTION

FROM \ TO	1 POULTRY	2 CATTLE	3 HOGS	4 BEEF	SUPPLY
1	.050 (500)	.03 (1200)	.065 (300)	.045	2000
2	.055	.035	.06 (1200)	.04	1200
3	.060	.03	.06	.035 (1000)	1000
DEMAND	500	1200	1500	1000	4200

The cost expresséd as negative numbers can be imposed on the distribution matrix as shown in Table 4. Thus:

$$.05x_{11}+.03x_{12}+.065x_{13}+.045x_{14}+.055x_{21}+ .035x_{22}+.06x_{23}+.04x_{24}+.06x_{31}+.03x_{32}+ .06x_{33}+.035x_{34}=\text{minimum} \quad . \quad . \quad . \quad . \quad . \quad . \quad [4]$$

Subject to storage capacities and consumption as indicated:

Storage	Consumption	
S_1=2000 cwt	D_1 (poultry)	= 500 cwt
S_2=1200 cwt	D_2 (cattle)	=1200 cwt
S_3=1000 cwt	D_3 (hogs)	=1500 cwt
S =4200 cwt	D_4 (beef)	=1000 cwt
	D	=4200 cwt

$$S_1=x_{11}+x_{12}+x_{13}+x_{14}=2000$$
$$S_2=x_{21}+x_{22}+x_{23}+x_{24}=1200$$
$$S_3=x_{31}+x_{32}+x_{33}+x_{34}=1000$$

and

$$D_1=x_{11}+x_{21}+x_{31}= 500$$
$$D_2=x_{12}+x_{22}+x_{32}=1200$$
$$D_3=x_{13}+x_{23}+x_{33}=1500$$
$$D_4=x_{14}+x_{24}+x_{34}=1000$$

The first feasible solution is obtained by starting at the upper left-hand corner, sometimes called the northwest rule, and filling in the maximum quantities which can be entered depending upon supply and demand. The first feasible solution shows a cost of $187.50. This is a feasible but not necessarily optimum solution. The next step is to determine alternative possibilities and select the optimum arrangement(4, 16). The values in Table 4 are feasible and, in this case, optimum.

The values used for the cost must be linear to apply in this configuration. Certainly it is difficult to foresee a linear relationship – that is, the same total cost per cwt to handle 100 lb or 1000 lb. The operating costs will be more nearly linear than the total cost.

The operating costs for handling by various methods, c_{mn}'s, can be assessed. The difference in operating costs:

$$(x_{mn})\ (c_{mn}-c'_{mn}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [5]$$

using two different methods, can be used to determine the amount of money which can justifiably be invested in one method compared to another method(24). The c_{mn} value can be used for different methods of handling such as manual, truck, belt conveyor, chain, flight conveyor, auger, portable wagon, or fluidized or pneumatic handling (Table 5). If it is known that method A costs 5¢ and method B 8¢ per cwt for operating cost for handling 1000 cwt per yr, $30.00 more per year could be invested in equipment for method B.

TABLE 5. ESTIMATED COSTS, c_{mn}, FOR ENERGY FOR HANDLING 1 TON A DISTANCE OF 100 FT BY DIFFERENT METHODS.

Fluid		*cost/ton*
Pneumatic(12)	1.3 hp-hr/ton	$.026
Pneumatic(15)	0.35 hp-hr/ton	.0070
Liquid-water-horizontal	0.015 hp-hr/ton	.0003
Free-flowing or non-free-flowing		
Flight conveyor	.044 hp-hr/ton	.00088
Auger conveyor	.16 hp-hr/ton	.0032
Belt conveyor	.02 hp-hr/ton	.0004
Manual		.75
Auger(17)	.42 hp-hr/ton	.0084
Truck		.012
Pallet		.001

Simplex method of linear programming. The simplex method of linear programming is used to determine an optimum assignment or allocation of materials as contrasted to the schedule which is optimized as covered by the transportation technique. Thus, the simplex method would be useful to solve such problems as the following:

(a) Most profitable mixture of ice cream to sell; optimum use of machine tools(26).

(b) Optimal program for mixing three grades of nuts(3)

(c) Planning economical cropping programs(8, 25)

The restrictions placed on a linear relationship are in the form of linear inequalities. If x is less than or equal to $y(x \leq y)$, and y is 10, x can be any value of 10 or less. By multiplying the inequality by -1, the relationship becomes $-x$ is greater than $-y(-x \geq -y)$. This relationship is of value to put an equation in comparable form with all the x's or y's on the same side of the equation. The solution to the following system of three inequalities:

$$x-y \leq 0,\ y-1 \geq 0,\ x-6 \leq 0 \quad . \quad . \quad . \quad . \quad . \quad [6]$$

The solution gives an infinite number of answers as shown by the shaded area in Fig. 8. If only one solution existed for the system of equations, the three lines would pass through a point. Thus, the simplex method is used to determine a number of solutions to systems made up of inequalities. An excellent reference on solving equations using the simplex method is presented by H. M. Wagner(27). In an equation as follows:

$$0.1x_1+0.2x_2+0.3x_3 \leq 500 \quad . \quad . \quad . \quad . \quad . \quad . \quad [7]$$

it can be changed from an inequality to equality by adding a slack variable, x_4, the prefix of which is identified as P_4.

$$0.1x_1+0.2x_2+0.3x_3+x_4=500 \quad . \quad . \quad . \quad . \quad [8]$$

The value for P_4, the slack variable, is one. Several equations are expressed as a matrix placing 0's where there are no terms. The slack variables, which have a coefficient of one as associated with column vectors, form a unit matrix with ones along the diagonal P_4 and P_n. The procedure of solving a problem is to progressively select new unknowns to solve the equation until the optimum set is chosen.

The following example illustrates the simplex method of solving mathematical programming. A farmer needs 1500 lb per day of ground feed. He may use a small electric motor driven 1-hp (100 lb per hr) continuous mill, g_1, up to 10 hr per day or a large grinder, g_2, driven by a 25-hp tractor (2000 lb per hr). After grinding the product can be handled manually —s_1, flight conveyor —s_2, or wagon and trailer —s_3. If processed at the second location, an additional 5¢ per cwt must be added for handling to the feed center (Table 6). (There is a maximum of 1 hr per day available for manual handling, which can be accumulated to 7 hr per wk). The P or vertical column represents the time in hours per 100 lb for various methods. Note that some of the spaces are left blank. For example, no manual handling is required for the continuous operation.

Let x_1 = hundred-weight of materials (per day) for process 1 under P_1, so x_n = hundred-weight of feed with various processes. Inequalities governing relationships:

$$\begin{array}{l|rrrrrrl} g_1 & 1x_1 & +1x_2 & +1x_3 & & & & \leq 10 \text{ hr/day} \\ g_2 & & & & .05x_4 & +.05x_5 & +.05x_6 & \leq .8 \text{ hr/day} \\ s_1 & .04x_1 & & & +.02x_4 & & & \leq 1 \text{ hr/day} \\ s_2 & & .002x_2 & & & +.001x_5 & & \leq 10 \text{ hr/day} \\ s_3 & & & .03x_3 & & & +.01x_6 & \leq 1 \text{ hr/day} \end{array} \quad . \quad . \quad . \quad . \quad [9]$$

The first step is to clear the above relationship of factors by multiplying by factors to provide whole numbers throughout.

$$\begin{array}{l|rrrrrrl} g_1 & x_1 & +x_2 & +x_3 & & & & \leq 10 \text{ hr/day} \\ g_2 & & & & x_4 & +x_5 & +x_6 & \leq 16 \text{ hr/day} \\ s_1 & 2x_1 & & & +x_4 & & & \leq 50 \text{ hr/day} \\ s_2 & 2x_2 & & & & +x_5 & & \leq 10{,}000 \text{ hr/day} \\ s_3 & & & 3x_3 & & & +x_6 & \leq 100 \text{ hr/day} \end{array} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [10]$$

Slacks variables x_7, x_8, x_9, x_{10}, and x_{11} are then introduced, which denote time not used and which balances the equation.

$$\begin{array}{l|rrrrrrrrrrl} g_1 & x_1 & +x_2 & +x_3 & & & +x_7 & & & & & = 10 \\ g_2 & & & & +x_4 & +x_5 & +x_6 & & +x_8 & & & = 16 \\ s_1 & 2x_1 & & & +x_4 & & & & & +x_9 & & = 50 \\ s_2 & & 2x_2 & & & +x_5 & & & & & +x_{10} & = 10{,}000 \\ s_3 & & & 3x_3 & & & +x_6 & & & & +x_{11} & = 100 \end{array} \quad . \quad [11]$$

These equations can be represented as follows, with P_n representing vectors (ordered set of numbers) for x_n:

$$P_1x_1 + P_2x_2 + P_3x_3 + P_4x_4 + P_5x_5 + P_6x_6 + P_7x_7 + P_8x_8 + P_9x_9 + P_{10}x_{10} + P_{11}x_{11} = P_0 \quad . \quad . \quad . \quad . \quad . \quad . \quad [12]$$

which represents

$$\begin{pmatrix}1\\0\\2\\0\\0\end{pmatrix}x_1+\begin{pmatrix}1\\0\\0\\2\\0\end{pmatrix}x_2+\begin{pmatrix}1\\0\\0\\0\\3\end{pmatrix}x_3+\begin{pmatrix}0\\1\\1\\1\\0\end{pmatrix}x_4+\begin{pmatrix}0\\1\\0\\1\\0\end{pmatrix}x_5+\begin{pmatrix}0\\1\\0\\0\\1\end{pmatrix}x_6+$$

$$\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}x_7+\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}x_8+\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}x_9+\begin{pmatrix}0\\0\\0\\1\\0\end{pmatrix}x_{10}+\begin{pmatrix}0\\0\\0\\0\\1\end{pmatrix}x_{11}=\begin{pmatrix}10\\16\\50\\10{,}000\\100\end{pmatrix} \quad . \quad . \quad . \quad [13]$$

TABLE 6. TIME TO HANDLE 100 LB BY VARIOUS METHODS, IN HOURS

Machines	Continuous Production at location 1			Production at location 2		
	P_1	P_2	P_3	P_4	P_5	P_6
g_1	1.0	1.0	1.0			
g_2				.05	.05	.05
s_1	.04			.02		
s_2		.002			.001	
s_3			.03			.01

Rearranging:

P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}
10	1	1	1	0	0	0	1	0	0	0	0
16	0	0	0	1	1	1	0	1	0	0	0
50	2	0	0	1	0	0	0	0	1	0	0
10,000	0	2	0	1	1	0	0	0	0	1	0
100	0	0	3	0	0	1	0	0	0	0	1

Note: unit matrix formed by slack vectors.

The values of x_1, x_2, x_3, x_n are determined through a repetitive process to obtain the combination which will accomplish the task in the least time. The example is given to illustrate the approval used in the simplex method. The procedure for solving is too lengthy for presentation here(3, 4, 26, 27).

Computers

Standard machine programs are available for linear programming on most computers. As computers become more plentiful and their operation more familiar, solving problems such as those presented here will be relatively simple. In a few years small transistor computors will be the standard equipment of the engineer, as the slide rule is today.

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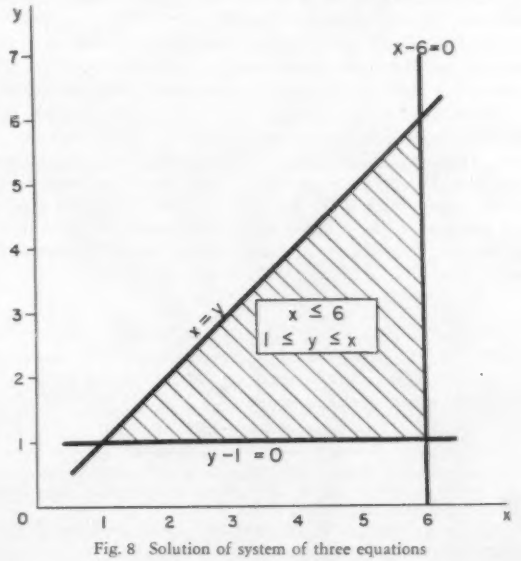

Fig. 8 Solution of system of three equations

Principles of Liquid Materials Handling

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Here's a brisk review of the principles governing liquid behavior. Then the author shows how to apply these principles to a typical liquid handling system

UNTIL recently most equipment for liquid materials handling was purchased as an entity with little regard to the overall farm operation. Now we realize that this equipment has to be selected as one link in a farm process system.

Liquid materials can be handled either in units or in bulk. For example, milk in a pipeline and tank system is transported and stored in bulk. Milk handled in cans is considered a unit system. The selection of the correct system and equipment is based on economy and convenience of operation. The economy, in turn, is measured by the unit cost of liquids handled. Since liquid readily lends itself to bulk handling, greater economy and convenience is usually obtained with continuous flow rather than with intermittent unit handling systems.

Properties of Liquids

An engineer designing a complete liquid handling system must be able to predict the behavior of the fluid handled under all conceivable conditions. He must thoroughly understand the following liquid properties and their interrelationships:

Specific weight is the weight of liquid per unit volume. It is expressed in units of force divided by volume. In the fps system, specific weight is expressed in pounds per cubic foot. Since the specific weight of liquids varies with temperature, the temperature has to be specified. For example, the specific weight of water 62.42 lb per cu ft at 32 F and 59.84 lb per cu ft at 212 F.

Density of a liquid is the mass per unit volume. In the fps system it is expressed in slugs per cubic foot. Water at 32 F has a density of 62.42/32.174 or 1.940 slugs per cu ft. The approximate density of any liquid equals its specific gravity multiplied by the density of water.

Specific gravity of a liquid is a relative term defined as the ratio of its density to the density of water at 39.2 F or 4 C. Since it is a ratio, specific gravity is expressed as a pure number.

The *viscosity* of a liquid is a measure of the internal friction or cohesion tending to resist flow. This resistance to flow, expressed as *absolute viscosity*, is the force required to overcome the unit shear stress at a unit rate of shearing strain. In the metric system, the unit of absolute viscosity is a poise and is measured in grams mass per centimeter second. In the fps system, the units are measured in pound seconds per square foot.

$$1 \text{ poise} = 0.002089 \text{ lb sec per ft}^2$$

Kinematic viscosity is the ratio of absolute viscosity to density. In the metric system, kinematic viscosity is measured in stokes or centimeters squared per second. In the fps system the unit is square feet per second.

$$1 \text{ stoke} = 0.00108 \text{ ft}^2 \text{ per sec.}$$

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September, 1958.

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In practice it is impossible to measure viscosity by a direct means. Instead, devices have been developed to measure the speed of flow of viscous liquids through tubular orifices, or the time required for a given quantity of fluid to escape through such an orifice. These time or flow rate measurements are quantitatively related to the absolute viscosity.

Surface tension is a measure of the intensity of molecular attraction per unit length along any line in the surface of a fluid. The surface tension of a liquid is usually given for that liquid in contact with air. Numerically, the surface tension is dependent upon the nature of the liquid itself, upon the properties of the adjacent liquid, and upon the temperature. As temperature increases, surface tension decreases.

All materials subjected to a load change dimensions. In liquids, this compressibility is measured by *bulk modulus*—the change in unit pressure divided by the corresponding change in unit volume under isothermal (constant temperature) conditions. However, in most farm systems the pressures are relatively low, and the liquids can be considered incompressible.

The relative resistance of metals to *corrosion* and *abrasion* are important criteria when selecting construction materials for a liquid system. The presence of moisture and oxygen is usually essential to corrosion. An acid solution will accelerate this action.

All metals are inclined to dissolve in water. The electrochemical or galvanic series is a relative measure of this tendency with respect to the common metals. The metallic positive ions can enter a solution only if positive ions of some other metal are displaced. In water, hydrogen is "plated out" and also acts as a protective film on the metal. The destruction of this film frequently caused by high liquid velocity over the metal surface or the presence of free oxygen to combine with hydrogen will cause corrosion to start. A low pressure area in a liquid system causing cavitation will result in rapid corrosion.

The presence of suspended solids in liquids accelerates abrasion. Increasing the liquid velocity also increases the rate of abrasion.

A liquid handling system is frequently used to convey a combination of two or more liquids or solids. For instance, in some sugar growing areas it is economical to handle and market sugar in a dissolved or liquid form. But before such a system can be designed it is necessary to accurately predict the behavior of the resulting combination. In such mixtures, two or more substances are intermingled, but each component retains its essential, original properties. Also, unless otherwise specified, there is no constant percentage composition.

An *emulsion* is a dispersion of fine globules of a liquid in a liquid. One liquid is in the dispersed or discontinuous phase while the other is the dispersing or continuous medium. For example milk is an oil-in-water type emulsion.

Suspensions are finely divided solids coarser than 10^{-4} mm mean diameter dispersed in a solid, liquid or gas. *Colloidal solutions* consist of finely divided solids between 10^{-4} and 10^{-6}

mm mean diameter homogeneously mixed with a liquid. In a *true solution* solid particles smaller than 10^{-6} mm mean diameter are dispersed in the solvent.

A *slurry* is a liquid, usually water in which foreign material of varying quantities is suspended.

Behavior of Liquids

Equally important to the system's design engineer is a thorough understanding of the behavior of liquids in motion or at rest. In a liquid at rest, the absolute pressure existing at any point is equal to the weight of liquid above this point plus the absolute pressure exerted on the surface. This pressure is equal in all directions and reacts normally to any contact surface. Assuming a homogeneous fluid or one with constant specific weight with the surface exposed to the atmosphere:

$$p=p_a+wh \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [1]$$

referring to water

w=62.4 lb per cu ft

h measured in feet

$$p=p_a+62.4h \text{ in psf} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [2]$$

If the atmospheric pressure is assumed to be zero (gage) then the gage pressure at any point in a liquid is:

$$P_g=sg\times 0.433h \text{ in psi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [3]$$

Fluids in motion present other important relationships. When a liquid flows in a pipe or conduit of variable cross section and with no cavities, the mass of fluid passing any given cross section is constant. For example, two points in a fluid system with area A_1 and A_2, velocity v_1 and v_2, and density ρ_1 and ρ_2:

$$\rho_1 \, v_1 \, A_1=\rho_2 \, v_2 \, A_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [4]$$

For an incompressible fluid there is no change in density and:

$$v_1 \, A_1=v_2 \, A_2=\text{constant} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [5]$$

If A is expressed in sq ft and v in ft per sec then the constant equals the capacity in cu ft per sec.

Three different forms of energy have to be considered when dealing with liquid systems: kinetic, potential, and pressure energy. In the fps system, energy is measured in foot-pounds. When referring to the unit weight of a fluid, the *specific energy* is measured in foot-pounds per pound or feet. *Potential energy* is due to position. For example, liquid stored at a 10-ft level has potential energy of 10 ft-lb per lb or 10 ft. Conversely, if a liquid is subjected to a pressure it has a certain *pressure energy*.

$$E=p/w \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [6]$$

The *kinetic energy* of a mass at a given velocity equals:

$$E=Mv^2/2=Wv^2/2g \text{ ft-lb} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [7]$$

In terms of specific energy:

$$E=v^2/2g \text{ ft-lb per lb or ft} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [8]$$

and is commonly called velocity head.

The total energy in a fluid is constant and equals the sum of kinetic, potential, and pressure energy:

$$Wh+(Wv^2/2g)+(Wp/w)=\text{constant (losses neglected)} \quad [9]$$

or in terms of specific energy:

$$h+(v^2/2g)+(p/w)=\text{constant (losses neglected)} \quad . \quad [10]$$

and is known as "Bernoulli's Equation".

Application to Fluid Handling

Conduits for conveying and directing the flow of liquids are broadly classified as closed conduits and open channels. Open channels are normally used for the transportation of liquids or suspended solids. Closed conduits may be used for either gasses or solids. Liquid in an open channel is exposed to the atmosphere, while liquid in a closed conduit is usually at some pressure other than atmospheric.

Liquids flowing in a conduit are subjected to a certain resistance. This resistance or friction is an important criteria in the selection and performance of hydraulic machinery and equipment. Frequently a major portion of the fluid head is dissipated in overcoming friction losses.

In computing the resulting friction losses for various components of the liquid system, it is necessary to determine the type of flow. The "Reynolds Number" is a convenient criteria for determining the flow

$$R=\rho vD/\mu \text{ or } vD/\nu \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [11]$$

Where:

v=velocity in fps

ρ=density in slugs per cu ft

D=internal diameter of pipe in feet

μ=absolute viscosity in lb sec per sq ft

ν=kinematic viscosity in sq ft per sec

Laminar flow exists below an R of 2,100, while turbulent flow normally exists above 3,000. Between 2,100 and 3,000 the flow may be either laminar or turbulent.

The friction head in a pipe for turbulent flow can be computed from Darcy's formula:

$$hf=f(L/D)\ (v^2/2g) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [12]$$

SYMBOLS USED IN THE DISCUSSION

A is cross-sectional area
Btu is the British Thermal Unit
K is bulk modulus
Q is capacity
gpm is capacity in gallons per minute
D is pipe diameter in feet
d is pipe diameter in inches
ρ is density
E is energy
ε is overall efficiency
ε_h is hydraulic efficiency
ε_m is mechanical efficiency
ε_v is volumetric efficiency
fps is foot-pound second
g is acceleration of gravity
sg is specific gravity
c is specific heat
h is height of column of liquid or head in feet
h_a is head in feet added
h_f is friction loss in feet
hp is horsepower
whp is water horsepower
M is mass in slugs
psi is pounds per square inch
psf is pounds per square foot
p is absolute pressure
p_a is atmospheric pressure
p_g is gage pressure
C is temperature – degrees centigrade
F is temperature – degrees Fahrenheit
R is Reynolds Number
is surface tension
v is velocity*
μ is absolute viscosity
ν is kinematic viscosity
w is specific weight
W is total weight

*Note similarity of symbols between v for velocity and ν for kinematic viscosity

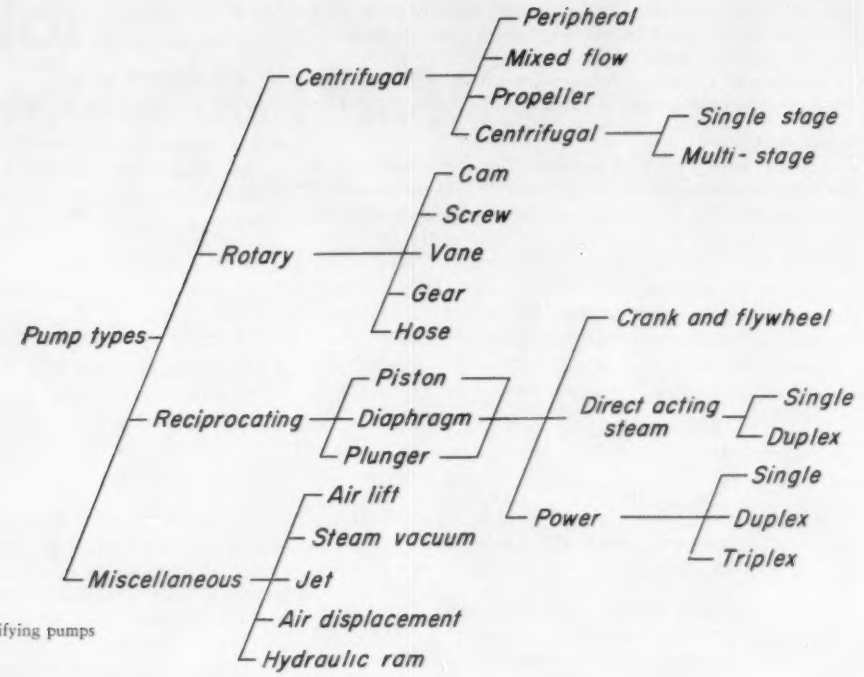

Fig. 1 One method of classifying pumps

. . . Liquid Materials

Where:

h_f = friction loss in feet of liquid
f = friction factor
L = length of pipe in feet
D = average internal diameter of pipe in feet
v = average velocity in pipe in ft per sec
g = acceleration due to gravity in ft per sec per sec

For laminar flow, the same equation is valid but $f=64/R$.

Friction losses for various types of couplings, elbows, valves, sudden enlargements can be computed from:

$$h=K(v^2/2g) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [13]$$

Where:

K = resistance coefficient for a fitting

Frequently the head loss of individual components of the liquid system is expressed in equivalent lengths of straight pipe having equal losses.

The source of most liquid systems is at a lower elevation or pressure than the discharge. With these systems, pumps are installed near the source to provide the required head. In other systems, such as the siphon type, gravity is used to produce flow. Where a siphon is used, some parts of the network are at a higher elevation than the source. As this height is increased, the flow rate is reduced or entirely stopped. Consequently, each siphon system has a limiting summit height depending upon the pressure at the base, vapor pressure, and friction loss. In any siphon system the pressure at the summit must be determined to establish flow conditions. Summit conditions are calculated by writing the Bernoulli Equation between the siphon base and summit.

Pressure systems require a pump to produce the required head for flow conditions. The power requirements for producing this pressure is readily calculated from the water horsepower formula:

Whp = lb of liquid raised per min $\times$ h in ft/33,000 [14]

or reduced:

$$\text{Whp} = \text{gpm} \times h \text{ in ft} \times sg/3{,}960 \quad . \quad . \quad . \quad . \quad [15]$$

Liquid Handling Equipment

The design of a liquid system for a particular handling problem requires the careful selection of each component. Before making this selection, the standard operating characteristics, abilities, limitations, and performance data of the required equipment must be known. Most of this information is available from the manufacturers. They should be consulted regarding possible uses. Versatility or flexibility should be another qualification for equipment selection.

Motivating Methods

In non-gravity systems, a motivating unit has to be used to produce flow. With these systems, the pump is an important item and has to be selected carefully. Both pump type and construction materials are important criteria for the selection of a suitable pump. Pumps are classified by various methods. One classification for the more commonly used pumps is shown in Fig. 1 (2, 23)*. The correct selection of a particular type of pump from the great variety available depends upon such characteristics as: *(a)* nature of fluid; *(b)* nature and importance of service; *(c)* source of liquid supply—elevation; *(d)* rate of discharge; *(e)* net suction head, discharge head and gross head; *(f)* availability and type of power; and *(g)* service factors such as cost, dependability, and useful life. For example, in one liquid system using high concentrations of wettable powders, a diaphragm pump had a much longer service life than did a roller vane type pump(11).

The correct selection of the proper materials for pump construction is an important consideration. Since this choice is based on the liquids handled, their physical and chemical

*Numbers in parentheses refer to the appended references.

properties have to be determined. Further, the age and operating temperature of the liquids have to be known since these influence the corrosive action. The rate of corrosion usually increases with temperature. Also, some liquids such as vegetable oils are relatively inactive when fresh but when exposed to heat turn rancid and become more corrosive. As a guide for materials selection, the Materials Specifications Committee of the Hydraulic Institute has compiled a list of some liquids commonly handled and the construction materials generally used.

Efficiency is another important criteria for selecting pumps. *Volumetric efficiency* is the ratio between measured output at a given pressure and the computed geometric displacement. At zero pressure and no leakage losses the volumetric efficiency is 100 percent.

Hydraulic efficiency is the ratio of the actual head developed to the head imparted to the liquid by the impeller. The actual head is lower because of friction and turbulence losses. For pumps other than centrifugal, the friction and turbulent losses are small and difficult to determine accurately. Therefore, the hydraulic efficiency is generally included as part of the mechanical efficiency.

The *mechanical efficiency* is the ratio of power delivered to the fluid and the brake horsepower supplied to the pump shaft. For a given pump, the *overall efficiency* is the product of hydraulic, volumetric, and mechanical efficiency. The power required to drive a pump is equal to the water horsepower divided by the overall efficiency.

Controls

The ultimate selection of suitable control devices for a fluid system depends upon the desired operating characteristics and required liquid pressures. Manually controlled gate, ball, or globe valves are frequently used for simple on-off operation. Needle valves are more applicable for controlling flow rates. On more complex systems, electric, pneumatic, hydraulic, or diaphragm valves regulate and control the flow sequence and rate. These valves are frequently used on automatic controllers that measure the control variable and produce a corrective action when it deviates from the set point limits. Automatic control action can be divided into: *(a)* simple on-off operation which produces either zero or maximum flow rate with no intermediate quantities, and *(b)* any degree of control adjusted between zero and maximum.

Irrespective of valve type or operation, the physical and chemical properties of the liquid must be considered in selecting the correct materials of construction. This includes packing and sealing materials as well as valve seats, bodies, stems, and fittings. Other salient features such as pressure loss, leaks, and possible contamination should also be considered.

Accurate measurement of fluid flow rate and quantity is an important aspect of modern liquid handling systems. In a closed pipe system, fluid flow can be measured by several different methods. The head meter operates by measuring the pressure differential across a suitable flow restriction. An orifice with an appropriate pressure-differential measuring device such as a manometer is a typical example of this meter. When using these meters, the location of the orifice plate and manometer taps are critical.

Area meters operate on the principle that the variation in area of a flow stream required to produce a constant pressure differential at a flow restriction is proportional to the flow rate. A rotameter with a tapered metering tube and suitable float is an example of this meter.

Special fluid velocity meters are also used indirectly to measure flow rates. The actual rate is the product of liquid velocity and the cross-sectional area. One instrument of this nature utilizes a turbine-type rotor suspended in the measured fluid. The rotor rotates at a rate directly proportional to the velocity of flow. Mounted within the rotor body is a small permanent magnet, polarized at right angles to the axis of rotation. As the rotor spins, this magnet sets up an alternating current in a coil of wire held within its field. The total number of pulses generated by the sensing element and picked up by electronic totalizer is directly proportional to the total quantity of liquid passed through the meter.

Another instrument of this type is the magnetic flow meter. With this device, the metered fluid flows through a magnetic field produced by electrically conducting coils placed parallel to the meter pipe. The resulting magnetic flux induces a voltage in the conductor or measured fluid that is directly proportional to its velocity, provided the field strength and conductor length remain constant. In this case conductor length is the diameter of the measuring pipe and does not change. The magnetic field strength can also be held constant.

The Thomas meter can also be used to measure the rate of fluid flow. This instrument's measuring system is based upon the rise in temperature of the metered fluid caused by the introduction of heat. The relationship between heat energy added, the temperature increase, and the rate of flow is:

$$v = 0.0569 \text{ volt} \times \text{amp} / Awc\,(F_1 - F_2) \quad . \quad . \quad [16]$$

Where:

v = fluid velocity in fpm
A = cross-sectional area in sq ft
w = specific weight of fluid in lb per cu ft
c = specific heat of fluid in Btu per lb F at constant pressure
F_1 = upstream or cool temperature
F_2 = downstream or hot temperature

The resulting error due to heat losses by radiation and conduction is minimized by maintaining a small temperature differential between F_1 and F_2.

Temperatures are generally observed by resistance thermometers or thermocouples.

A quantity meter measures the time integral of flow rate of a fluid passed through the meter. This is accomplished by passing the measured fluid through the meter in distinct increments by filling and emptying containers of known weight or volumetric capacity. The quantity of flow is determined by totalizing the number of increments.

Basically there are two kinds of quantity meters: *(a)* those that weigh discrete increments of liquid and *(b)* those that pass discrete volumes of liquid. Weighing meters operate on the beam-balance principle and determine the true weight-quantity of flow. An example of this type is the tilting trap meter. The trap is designed in such a manner that when liquid fills the container the resulting center of gravity passes over the stable equilibrium point and the trap automatically upsets. These meters are mechanically arranged for continuous flow by employing two tilting traps or by temporarily diverting the liquid to a holding chamber during the dumping operation.

The volumetric quantity meter operates on the principle of filling known volume voids with the measured liquid and discharging this liquid through the outlet. Some examples of this type are reciprocating piston, rotary-vane, nutating-disk, and lobed-impeller meters.

Fluid flow in open channels is measured by various shapes of weirs and hydraulic flumes. Propeller type current meters also measure flow rate and quantity. Small flows can be accurately measured with a proportional weir(27).

When selecting the correct flow meter for a given system the density, viscosity, pressure, temperature, and flow of the measured liquid must be considered. For example, a head meter

(Continued on page 538)

Here are the engineering principles involved in

Flow of Bulk Granular Materials

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This discussion is concerned primarily with the nature and stability of flow of bulk granular materials in and out of storage bins, hoppers and spouts. Information is needed for designs of economical handling systems which will insure a positive rate of flow. Therefore, the knowledge of flow behavior of granular materials in relation to the physical factors affecting it is important

THE distinction between free-flowing and non-free-flowing materials is largely an arbitrary one. A completely free-flowing material would have no friction among its particles and, therefore, a zero degre angle of repose. In other words, it could not be piled. However, grains such as wheat and shelled corn do repose by virtue of friction among the individual grains. Nevertheless, they are considered to be free-flowing materials. Such grains as oats and rough rice are even less so, because of greater internal friction. Moreover, grain can quickly lose its flowability when it contains a large amount of cracked grain, foreign material, and moisture.

Grain Flow In and Out of Bin

The behavior of grain in filling and emptying a bin has been well described by Bailey (1)*, Ketchum (5), and Caughey (2). Dry grain flowing from a spout will form a conical pile. The slope will be somewhat less than the angle of repose, due primarily to the impact of the flowing stream. The slope of the pile is also affected by the moisture content of the grain and the amount of chaff, dust, fine material and broken kernels.

In the process of filling a bin, grain tends to separate into lighter and heavier components. The heavier ones remain in the center under the grain stream and the lighter float out toward the wall. This results in a somewhat compacted core of higher dockage grain in the center of the bin.

The bin may be emptied by gravity flow through discharge openings located anywhere in the bin bottom or in the side wall near its base. In other words, the opening may be vertical as well as horizontal. However, as will be pointed out later, it is best to empty a storage bin near the center. To facilitate handling, conical shaped hoppers allow the bin to empty completely.

In emptying, as in filling, the lighter particles again separate and leave the bin last. The column of grain directly above the discharge opening leaves first and gradually widens out as it reaches the funnel-shaped grain surface, which follows the core until the last grain to leave is that in the hopper. Literally, the bulk of grain turns itself inside out. If the storage has a flat instead of a hopper bottom, the remaining grain forms a hopper or funnel of its own with a slope angle considerably greater than the angle of repose (Fig. 1) (8). This pattern of flow is referred to as *funnel flow* (3).

Now, if a very steep sloped hopper is used, the pattern of flow changes. The whole mass of grain flows down simultaneously, including the otherwise stationary material in the hopper. The flowing core increases in diameter until it includes all of the material in the hopper. This flow pattern is referred to as *mass flow* (Fig. 1C).

When a bin is emptied through a vertical opening in the side wall, the discharge rate is nearly as great as through a horizontal opening of the same size in the bottom. The grain does not spout (as in the case of liquids) but flows at a constant rate until the level of the grain reaches the discharge opening. In other words, it is independent of the head or the depth of grain.

From observations in model bins, the pattern of flow through a side discharge opening is somewhat different from that through a center discharge (5), as shown in Fig. 1. The funnel-shaped depression of the grain is usually formed at first on the side opposite the discharge opening. But it moves gradually across the bin to the discharge opening as the bin is emptied. However, exceptions to this pattern have been observed. In full scale bins the depression is generally formed directly over the discharge opening. This pattern of flow has also been observed in model bins by Caughey (2).

There are some important design considerations of the storage bin depending on how it is filled and emptied. These include the unused storage space and the magnitude and distribution of loads on the bin walls.

Changes in grain pressures on the walls of the storage structure during emptying have always been the subject of considerable study (2, 5) to provide reliable information for economical and safe design. In a center discharge (Fig. 1A, C and D), both the lateral pressure on the wall and the vertical load on the floor increases only slightly. This is due to the breaking of the arch or dome of grain. Now, when the grain is removed from a side opening (Fig. 1B), the lateral pressure on the side wall next to the opening decreases, but that on the opposite wall increases appreciably. An increase of as much as 30 percent has been observed in model bins. Ketchum (5) states that under common conditions an increase of 2 to 4 times the lateral pressure of grain at rest may be expected.

Observations of steel tanks with side discharge show that provision must be made to prevent buckling of the wall directly above the discharge opening, indicating that the vertical wall loads are also much greater here, than where grain is at rest. Also, the unequal wall loading due to the non-symmetrical grain surface is manifested by *egg-shaping* of the tank wall, especially in the upper part of the bin where lighter gages are ordinarily used.

The shape of the grain pile after filling depends on the location and direction of the filling spout, as shown by typical surface profiles in Fig. 2. The shape of the bin roof and location of spout affect the amount of unused space. Filling at the center (A) wastes considerable space, but filling at the side (B) wastes more. Very little space is unused with a distributor or spreader (C) or when a cone-shaped roof is used (D) with a slope of about 30 deg, which is somewhat greater than the angle of repose. The latter may be filled completely to the peak of the roof. Subsequent settling (2) will provide enough space for admitting air for aeration.

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The author — H. J. BARRE — is consulting agricultural engineer, Mansfield, Ohio.

*Numbers in parentheses refer to the appended references.

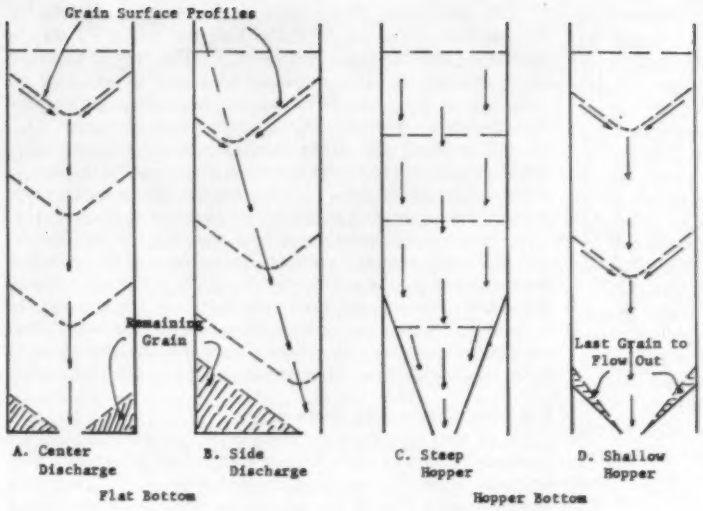
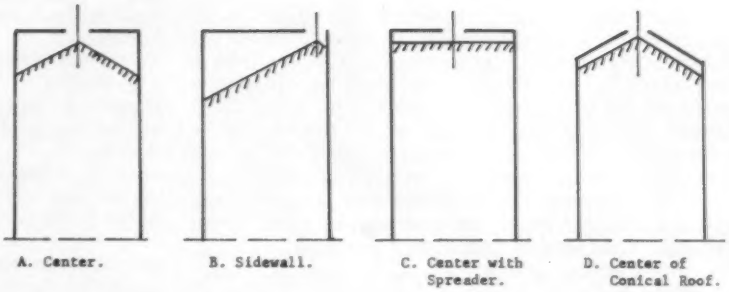


Fig. 1 *(Left)* Patterns of grain flow in center and side discharge

Fig. 2 *(Right)* Typical profiles of grain surfaces after filling storage



Flowability of Bulk Granular Materials

Handling relatively free-flowing materials such as common grains is so highly developed through many years of experience that the underlying principles are taken for granted. However, common grains under some circumstances and conditions can very easily become relatively non-free-flowing due to the presence of dust, cracked grain, and foreign material. Damp grain, even if stored temporarily, exhibits poorer flowing properties than dry grain. The settling of grain in storage further impairs its flowability, not to mention caking due to heating even in initial stages of deterioration (4, 7). For any relatively free-flowing material the stability of flow is determined by the size of the discharge opening and the slope of the hopper.

An analytical and experimental study has been made recently by A. W. Jenike at the Utah Engineering Experiment Station on the flow of bulk solids in bins (3). Jenike states that the problem of flow or non-flow of bulk solids out of storage is primarily one of strength of the bulk material. When the bulk solid is loose it has no strength. But in storage it builds up strength from compacting pressures due to its weight and from its own impact in filling. Vibration may also contribute to compaction. The more it is compacted, the greater is its strength. It will flow from storage when the internal pressures exceed its strength. If it has sufficient strength to resist the pressure, flow is obstructed.

Typical Obstructions to Flow

Two principal obstructions to flow are *doming* and *funneling*. Both are a form of arching or bridging associated with convergent flow of granular material in which it is necessary for the bulk material to lose its strength to become flowable.

Doming commonly occurs over the discharge opening. When the discharge gate is opened the grain under the dome flows out. If the weight or pressure above the dome exceeds its strength, the surface of the dome ruptures with resulting flow. If not, an obstruction called doming occurs. Experiments with transparent walled bins (5) show that the grain from the center discharges first. It drops through the top of the dome while that in the lower part of the dome discharges last.

Granular material such as grain will flow into the funnel-shaped depression at the surface where the material is least compacted. Even this may not take place with less free-flowing material. An open core may form, extending from the discharge opening up through the bulk and the surface or the material may be discharged from the storage to a level where the stationary material is more compacted; that is, it has greater strength to resist flow, as shown in Fig. 3. This typical obstruction to flow is referred to as *funneling*.

Conditions for Stable Flow

Jenike (3) has developed some important physical relationships through mathematical analysis and experiments between the maximum span of opening and certain physical factors beyond which a granular material of a given compacted strength can form or maintain a stable dome. In a rectangular or elliptically shaped opening the width of the opening B is given by the relation,

$$B > b_h b_v \, (f_c/w) \sin 2\theta,$$

where b_h and b_v are coefficients depending upon the shape of the hopper at the opening, f_c is the unconfined compressive strength for the greatest compacting pressure in the bin, w its bulk density, and θ the slope angle of the principal pressure

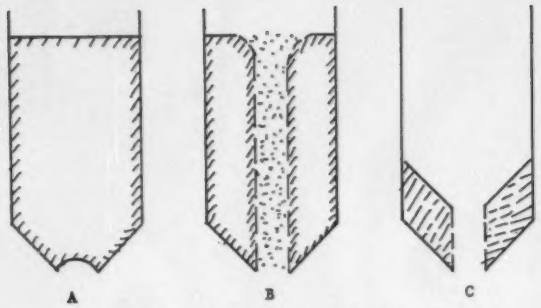


Fig. 3 Typical obstructions to flow in hopper bins. A, doming; B and C, funneling

of the material on the hopper wall. Sin 2θ is a function of the hopper slope, friction angle between material and hopper, and the ratio of the unconfined compressive strengths, f_a for adhesion and f_c for cohesion†. It is a maximum of 1, except for very steep and smooth-walled hoppers.

The coefficient b_h depends on the ratio of the length of the discharge opening L to the width B. It equals a maximum of 2 when $L/B = 1$, and a minimum of 1 when the ratio is greater than 2. The coefficient b_s depends on the vertical cross section of the hopper along its minor axis. Its estimated extreme values for a wide range of the internal friction angle ϕ, and the mean unit compressive strength of the bulk material f_c/w in the hopper, vary between 0.72 and 0.96.

Another requirement for stable flow must be met to insure against funneling in the bin above the hopper. Consideration by Jenike on this problem leads to the flow formula,

$$D > B + d\,(f_c/w)$$

where D is the width of the bin and d is a coefficient dependent on the ratios L/B and D/B. The values of d lie between 2 and 5.5.

Pressures in Bulk Granular Material

It is apparent from the above that pressures within the bulk, from whatever source, are most important in determining flowability of bulk material from hopper bins. The *flow factor* f_c/w of a bulk material, so named by Jenike, is a function of the vertical pressure v, and is expressed as follows:

$$f_c/w = F(v/w)$$

where w is the bulk density. Both ratios f_c/w and v/w are linear and are referred to as the unit strength and unit compacting pressure, respectively.

Three sources of pressure compact the material in storage and give it strength: *(a)* its own weight or static pressure, *(b)* impact from the falling material, and *(c)* vibration. Each of these may contribute to compaction. For example, the impact from a concentrated stream of grain flowing into the top of a high tank at a high rate of feed becomes an important contributing factor as well as the weight of the grain itself. In addition, the pressure may also be induced by vibration, especially if prolonged, through rearrangement of particles and subsequent settling. It is a major factor in contributing to the pressure and subsequent strength of uncompacted material.

†$f_c = 2\,c \tan (45° + \phi/2)$. $f_a = 2\,a \tan (45° + \phi'/2)$. where c is cohesion and a is adhesion per unit area, and ϕ is the friction angle of the material, and ϕ' the angle of friction between material and wall. For derivations of these formulas and experimental determinations of the "effective" cohesion, c, and adhesion, a, consult reference (9) and other books on soil mechanics.

The distribution of the static vertical pressure v along the vertical axis of the hopper bin (illustrated in Fig. 4) may be estimated from Jannsen's formula (5). The vertical pressures along the vertical axis are chosen because it is here that the pressures at any given elevation are the greatest. Therefore, these pressures determine the maximum bulk strength.

The gradient AB of the vertical pressure v in the cylindrical portion of the bin increases from zero at the surface to a maximum at its base. In the hopper the pressure drops sharply from B to C, but increases again to a maximum at D after which it decreases to zero at the apex of the hopper. The indicated pressure gradient FD in the hopper represents the estimated pressures without any grain in the vertical portion of the bin and has been assumed to be the same as the upper part of the pressure gradient AB in the bin. These portions of the vertical pressure gradients are the same as those in shallow bins. They are, therefore, nearly hydrostatic.

Reducing Compacting Pressures

It is obvious that the strength of the material can be reduced by simply reducing the compacting pressures. This has been done in practice in a number of ways. To reduce obstructions to flow in the hopper, the pressure in the hopper may be reduced by placing a shelf at the center about mid-height in the hopper. This will reduce the maximum pressure substantially and has been used successfully in eliminating obstructions to flow in sawdust (6).

According to Jenike, it is also desirable to reduce the pressure in the cylindrical portion of the storage, especially with relatively non-free-flowing materials. This has been done in several ways. One is to install a criss-cross partition at the center of the bin. This reduces the effective diameter by about one-half and effects a substantial reduction in pressure, indicated by the gradient AB' in Fig. 4. The maximum pressure at the base of the bin wall is reduced to nearly one-half that without the partition.

Another means of reducing the pressures in the cylindrical portion of the bin is the use of continuous ledges on the side wall at selected elevations. Horizontal disks on cables have also been used.

Obstructions to continuous and uninterrupted flow in spouts are caused by either impact or vibration, or both. Here

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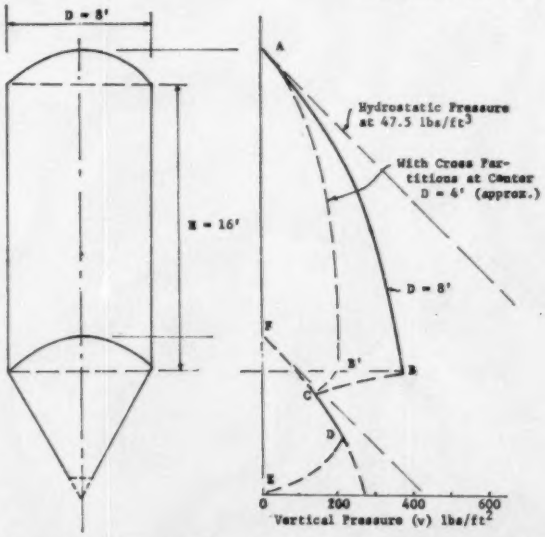

Fig. 4 Vertical pressure along vertical axis in hopper bin, estimated by Jannsen's Formula for shelled corn, $k = 0.654$, $u' = 0.36$ and $w = 47.5$ lb per cu ft

. . . Handling Materials

(Continued from page 523)

in the trade as "whole goods," equipment for handling materials on farms consists mainly of components or dependent units. They must be linked into a smoothly operating system. Such systems demand that the method for performing such operations be compatible and complementary. Also, the units must be coordinated and integrated into an economical entity for continuous flow and simultaneous performance.

Most farm equipment dealers are allied with one or a few major manufacturers from whom they obtain their inventory of resale goods. Very few of these manufacturers are making major components or complete systems for handling materials on farms. This imposes two new management problems on established retailers of farm equipment. The first is to select from the trade offerings those components which seem to fit most work requirements in the territory served. This means alignment with several new suppliers either directly or through wholesale distributors. A second problem involves the aspects of finance discussed more fully later.

The effects of most field operating equipment are well known. Dealers can usually demonstrate equipment on the farm of the prospect. Materials handling equipment, in most sales situations, does not lend itself readily to demonstration on the farm of the prospect. Furthermore, the effects are less tangible. The farmer's time and energy saved are more a statistical fact than an observable fact. That is, the benefits can be rationalized more readily than they can be perceived. These two merchandising aspects of materials handling equipment could present serious obstacles to a great many dealers because of their present form of business organization and the methods used in supplying themselves with equipment, financing that inventory of resale merchandise, and in presenting and selling it to farmers.

The powering of such equipment is also foreign to the great majority of farm equipment dealers who are more familiar with the internal combustion engine than with the electrical motor – the prime mover for most materials handling equipment.

Engineering and construction have not been in the tradition of the retail trade.

The Aspects of Finance

From the marketing viewpoint there are two distinct financial aspects to farm materials handling equipment. The first is from the standpoint of the retail dealer who must stock such equipment. Traditionally he has depended upon his main supplier for financing by a form of consignment selling. Most of the major manufacturers have ready access to the major money markets and can establish a separate corporation for holding such notes or can make arrangements with financial institutions to support such a deferred payment plan. Most specialty equipment manufacturers are not in this credit class. Even the established financial institutions, familiar with financing farm equipment dealers, will find the financing of a great variety of comparatively low unit value components outside their experience and tradition.

The second financial aspect of farm materials handling equipment is in the financing of farmers' investments. Country banks familiar with financing feed, livestock, and other production supplies, as well as investments in capital goods, are more familiar with credit instruments covering but one unit and for a relatively short term. Materials handling equipment, involved as it is with construction and engineering, will call for loans of larger amounts and for longer maturities to finance a complete system. This has been outside the tradition and the experience of the country banker and the financial institutions financing farmers.

I have tried to show that all of the agencies engaged in what we term "marketing," or the movement of goods and the transfer of title, are partially, and in some cases totally, unfamiliar with the new requirements imposed by materials handling equipment.

My objective in dwelling on these points is to caution against an exclusive devotion, on the part of the engineer and the manufacturing firm, to innovations or product improvements. If we are to manage this transition in marketing, we must encourage open and frequent discussion of the several important aspects of retail distribution.

Continuous and close observation of farm equipment marketing indicates to me that this is largely unexplored territory. It represents our outer space of selling. The electrically inclined agricultural engineer, the management engineer, the electronics technician and the farm management consultant will all very likely play important roles in its conquest. There is good reason to believe that they, operating as a team, will be as instrumental in raising the level of farm productivity in the livestock enterprises as were their earlier counterparts in raising the level of farm labor efficiency in crop production.

In assessing the prospects of farm materials handling equipment and farm materials handling systems from a marketing point of view, I would be remiss if I did not point out the importance of price considerations. Components of systems will have to be designed and produced and marketed at a price that will permit them to fit economically into total systems that can yield measureable savings. It is one thing to put cost accountants and engineers to work as a team on a product which will be produced or at least assembled principally in one plant and offered as a complete unit. It is quite another problem to market a unit which must be integrated into a system and have its price proportionate to its contribution in the total system.

To realize the potential in this field we must motivate farmers to accept recommendations and to invest in required power, equipment and structures. That will require coordinated educational effort involving many agencies, such as: The Extension Service; Vo-Ag teachers; commercial farm information agencies; manufacturers and distributors of equipment; and bankers and other financial agencies.

Although there may be breakthroughs ahead spurred by the imagination and ability of a talented individual, most of our progress will result from concerted effort and coordinated teamwork.

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. . . Liquid Materials

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used to measure pulsating flow does not register the correct value of average flow, but tends to read high when square-root compensation is not provided. Another possible error is due to viscosity. Since viscosity varies with temperature, the temperature of the metered fluid must be held nearly constant. The physical and chemical properties of the liquid must be considered in selecting the proper meter construction materials. Where human foodstuff is involved, stainless steel and glass are generally used.

Putting Theories to Work

The interrelationship of all phases of liquid materials handling is best illustrated by a typical example. Assume that management decides that it will be economical to feed a molasses supplement to dairy cattle. This molasses is available in 55-gal barrels. The problem is to design a suitable system to permit this feeding.

No matter what the size of operation, the first consideration is the feeding location. Since grass silage is used in the feeding schedule, molasses can be economically added to the silage during the silo filling operation. Additional benefit is gained since molasses acts as a preservative. Also, less labor is involved in feeding molasses with silage as compared to: *(a)* straight feeding *(b)* sprayed on feed or *(c)* mixed with feed.

The second consideration is how to mix the molasses with the silage. Two possible methods are available(10). If a pumping system is used, molasses can be mixed with the silage at the upper end of the blower pipe near the top of the silo. If gravity is used, molasses can be mixed with the silage in the side of the blower fan housing. Since there is no danger of gumming up the blower or blower pipe using the top distributor pipe, this method is selected.

The third consideration—physical and chemical properties of molasses—is necessary to determine the proper pipe sizes, power requirements, pumping unit, metering unit, and construction materials. Individual lots of molasses vary to some extent in their constituents. Difference in percentage of water causes variations in the behavior of molasses. One sample(8) contained 48 percent sugar, 12.19 percent other carbohydrates, 4.81 percent crude protein, 12.44 percent ash (mineral matter), and 22.56 percent water. In addition, molasses contains varying quantities of dissolved and entrained air and CO_2.

The weight and viscosity of molasses varies greatly with temperature. At temperatures below 100 F, it weighs between 11.5 and 12 lb per gal. This weight decreases with temperature. At 210 F it weighs only approximately 6 lb per gal. The viscosity of molasses also varies with water and resin content. The resin content in turn is dependent upon the variety of cane, soil on which it is grown, height of cut, and the refining process. At 70 F one sample had an absolute viscosity of 109.7 poises, while a different molasses at this temperature had a viscosity of 450 poises(28). For any given sample, an increase of 10 F reduces the viscosity approximately one-half. The addition of 10 percent water by weight to molasses is equivalent to heating straight molasses approximately 60 deg.

The specific heat of molasses is approximately one-half that of water or 0.5 Btu per lb per deg F. When overheated molasses carmelizes and becomes a solid. While it is frequently economical to heat molasses to reduce the viscosity, the procedure could be disastrous.

Straight molasses is relatively non-corrosive and can be stored indefinitely in steel containers. Diluted molasses tends to ferment and becomes more corrosive. Since fermenting and carmelizing are undesirable, the system is designed to handle undiluted and unheated molasses.

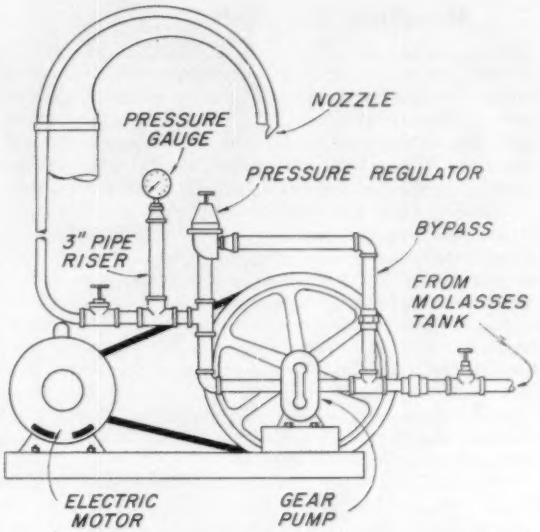

Fig. 2 An example of a farm liquid system showing the pump and piping arrangement for handling molasses

The fourth consideration is equipment selection and power requirements. For this example, the size of equipment and consequent power requirements are based on 70 lb of raw molasses per ton of green silage. Using a blower elevator with a maximum capacity of 1000 lb per min for a 30-ft silo, the liquid system must have a capacity of at least 35 lb of raw molasses per min.

Based on required capacity, molasses viscosity, and desired flexibility of the system, a 1-in polyethylene flexible discharge tube is chosen. This pipe is light weight. It can be easily taken down, cleaned with water, and coiled for future use.

The total pressure required to pump the molasses is next calculated. Using Bernoulli's Equation[10], the total head added equals:

$$h_a=(v^2/2g)+h+h_f$$

Before h_f can be calculated, the Reynolds Number—Equation [11]—has to be determined. Pumping 3 gal of molasses per min with a kinematic viscosity of 10,000 Seconds Saybolt Universal at 70 F:

$R=4.3$ which indicates laminar flow.

The total head loss due to friction computed from Darcy's Formula—Equation[12]—

$h_f=102.5$ ft, $(v^2/2g)=0.023$ ft, $h=30$ ft

Total head added equals 132.523 or 132½ ft.

A rotary external gear pump is selected since it is relatively inexpensive and will handle molasses with entrained gas. Bronze is selected as the pump construction material(23). To prevent the molasses from carmelizing, the pump size is based on the required capacity at 100 rpm. A 1-in. pump with a capacity of 4 gpm at 100 rpm is used.

Power requirements are calculated from Equation[15] and an overall efficiency of 40 percent.

hp=0.35 or a ½-hp electric motor

Fig. 2 is a schematic diagram of the overall system.

This system is only one possible solution of a typical problem. It is not intended to serve as a guide for handling molasses. The practical aspects of liquid feeding are included in Hansen's article(13).

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(Continued from page 536)

the static pressure is low and not a factor in building up strength. To prevent obstructions, the rate of feed into a spout should be controlled, either at the inlet or outlet, to prevent impact. Controlled feed at the inlet will not allow the spout to flow full. On the other hand, with control at the outlet the spout should flow full and should never be allowed to run out of material. In either case there is no opportunity for the material to impact. Precaution against vibration of the spout should be taken in a full flowing spout.

Summary

There are many independent and inter-related factors which affect the stability of gravity flow of bulk granular materials from storage bins. The most important of these is its bulk strength which results from compaction due to pressures from its own weight, impact in filling, or even vibration. To make the material flowable its strength must be overcome and the material allowed to become loose. Obviously, one of the best ways to obtain this condition is to keep the bulk strength to a minimum through reduced pressures. This has been accomplished in a number of ways. One is through vertical partitions at the center of the bin. Another is by continuous supporting shelves at vertical intervals on the bin wall and by a single supporting shelf in the center of the hopper. Spreaders under the filling spout to reduce impact, and insulation against vibration may assist materially in keeping pressures to a minimum.

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Handling Non-Free-Flowing Materials

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Results of a study of methods of moving materials out of bulk storage based on material characteristics that encourage flow

MANY of the agricultural commodities handled on the farm are non-free-flowing materials. Silage, hay, manure, moist grain, and some ground feeds are examples. Millions of tons are involved annually and yet little has been done to study the materials in relation to handling.

To handle non-free-flowing materials when they are stored in bulk requires that they be transformed into free-flowing materials for the period of time when handling occurs. Where translocation is required, getting the material from storage onto the conveying device presents the greatest difficulty. In the past, mechanical and pneumatic agitation have been used with bottom unloading from storage, and special machines have been used for both top and bottom unloading.

Since the movement of these materials out of bulk storage is of tremendous importance, this paper will deal with this subject only. Recently some new methods of moving materials out of storage have been devised and studied. They are based on the use of material characteristics that encourage flow.

Intermediate between solids and fluids are materials classified as semifluids. Under some conditions these materials have flow characteristics approaching those of solids, and under others their characteristics approach those of fluids. Dry materials of almost symmetrical shape, such as sand and wheat, are almost perfectly flowing semifluids. The particles are held in place by friction on each other and without cohesion. Since they flow easily, they are called free-flowing materials (1)*.

The addition of a cementing material between the grains, or a change in the characteristics of the material itself, causes cohesion in the mass. When cohesive forces are present, the material may become non-free flowing.

Masses composed of irregular, granular or fibrous materials will interlock with each other. The degree of interlocking will determine the ability of the individual particles to slide or roll over each other. This will also influence the flow characteristics of the material.

For non-free-flowing materials, the angle of internal friction and the angle of repose are not synonymous because of the presence of interlocking and cohesive forces. The angle of internal friction is the angle whose tangent is the coefficient of internal friction of the particles upon one another and approaches 90 deg as a limit. The angle of repose is the natural slope which a granular mass will assume, when the slope is created without the addition of energy to the system. A slope created by material falling from above will develop an angle less than the angle of repose. The slope can be tilted up after formation, and flow will occur at some larger angle. This is the angle that would have been created if energy of impact had not been added to the system. Only in special cases are the angle of repose and the angle of internal friction equal or approximately equal to each other for granular materials. This will be shown later. Since some of the non-free-flowing materials can repose at angles of 90 deg or larger, a new term, such as the "angle of form," should be used to describe the material, because it would measure resistance to sliding. The mass is usually unstable under these conditions; disturbances will cause it to flow to a new form.

Non-free-flowing materials can be categorized as those that will not fill in after a portion is removed. (The angle of friction and angle of repose are not equivalent.) The surface of the mass exposed by the removal may exhibit an angle of form up to 90 deg and larger.

Usually, when materials are removed from storage they are asked to flow by gravity from the interior of the mass through an opening in a hopper bottom. This severely limits the range of characteristics, like moisture content, shape of particle, size distribution, etc., that determine whether the material will flow or not. This will be seen from the following explanation:

Uniformly cover an annular disk with a layer of material equal in height to $(r_b - r_a)$ tan ϕ or greater (Fig. 1*a*). The extent of the material covering the disk should be great enough so that the boundary conditions will not influence movement of any of the displaced material. By at least three supporting elements carefully lift the annular disk with the material it will support. Determine the external and internal angles of form, ϕ and α, respectively. The external angle ϕ should approximate the angle of repose; the internal angle α should be equal to ϕ or greater depending on the characteristcs of the material. Since their angles need not be equal for the same material, the angle of repose is equal to the angle of internal friction only under more rigorously defined conditions than normally used. The angle of repose must be measured by using a plane surface on which lateral flow occurs.

The angle ϕ shows how the shear strength of the material is influenced when it lies on an expanding surface. The angle α shows how it is influenced when the material lies on a contracting surface (Fig. 1*b*). In the former, the particles are freed from each other; in the latter, they are more tightly locked to each other. Cohesive forces in the contracting surface are increased because side pressure increases, and interlocking forces are increased because of the tightening action (Fig. 2*a*).

Using sand as an example, as the moisture content increases both angles, ϕ and α, increase, but α increased at a faster rate than ϕ. The rate of increase in relation to ϕ is relative, and it is predicated that it depends on r_a. As r_a is increased, the rate of change of α in relation to ϕ decreases.

Surfaces studied on the resulting sand form developed on the annular disk show the formation of a stable arch on the

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*Numbers in parentheses refer to the appended references.

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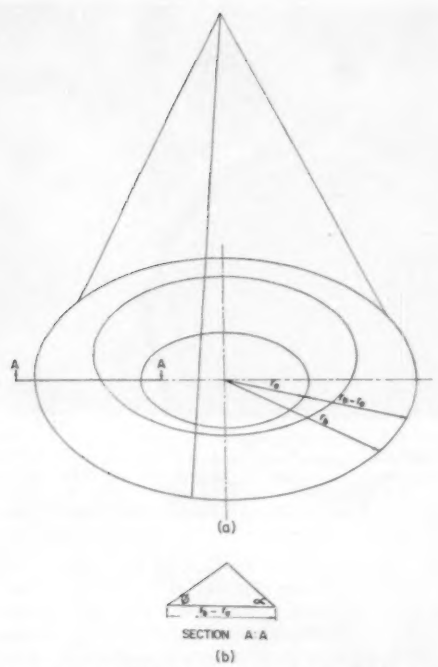

Fig. 1 *(a)* An annular disk when lifted through a granular material will support material whose cross section is triangular in shape. The radius of the inside opening of the disk is r_a and the outside radius of the disk is r_b. *(b)* The triangular cross section has a base of $(r_b - r_a)$. The external surface, called the expanding surface, makes an angle of ϕ with the base; the internal surface makes an angle of α with the base.

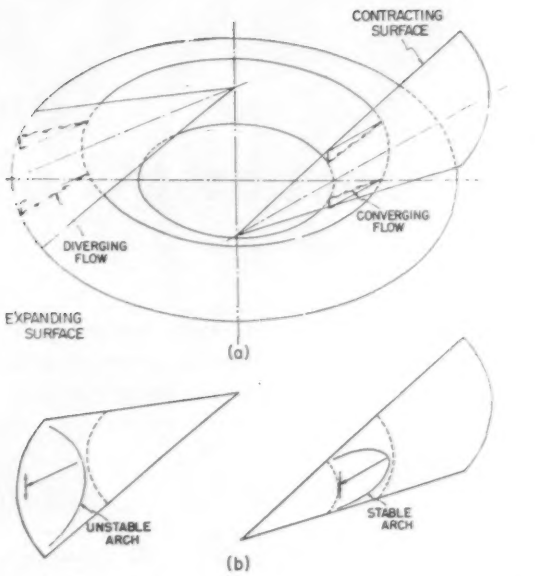

Fig. 2 *(a)* Segments of the expanding and contracting surfaces extended to their apexes can be used to illustrate diverging and converging flow. On the expanding surfaces flow lines diverge, on the contracting surfaces flow lines converge. *(b)* With diverging flow the two components of displacement are oriented so that an arch that is described on the surface is subjected to tension. With converging flow the two components of displacement are oriented so that an arch is subjected to compression. An arch is unstable when subjected to tensile forces and stable when subjected to compressive forces

internal surface and an unstable one on the external surface (Fig. 2*b*).

From this discussion, it can be concluded that flow from the outer or expanding surface will occur over a wider range of characteristics normally tending to limit flow than flow from an inner or contracting surface. A device utilizing this principle has been created. It is called the BCR easy-flow bin and is a bin discharge device, Fig. 3 (2). With this device, created for coal, the coal empties from the periphery first, the interior second. Reports show that coal having a moisture content in excess of five per cent will not satisfactorily flow out of a hopper bottom bin of conventional design (3). Using the easy-flow bin, coal of 18 percent moisture content is reported to flow satisfactorily. A 28 percent moisture content sample flowed reliably when a vibrator was used on the bin (2).

The bin discharge device, when used with a bin holding a granular material, will enable it to be emptied by free flow or assisted by a vibrator. The diameter of the required top opening of the bin discharge device, where it is attached to the bottom of the bin, should depend on the characteristics of the material. Flow to the interior approaches flow to the exterior at some value of r_a, and it should be different for each material.

The first principle of handling materials classified as non-flow materials is to exploit the characteristics that enable them to flow or to show a tendency to flow.

This principle has been applied with some success to the design of a silo that empties from the bottom and is used to store a fibrous material (4). A fibrous material is most unlike a granular material since it interlaces. Because of this it might seem illogical to consider it in relation to flow but, when examined, fibrous materials show a tendency to flow. It is limited by certain characteristics, principally the length of the fiber.

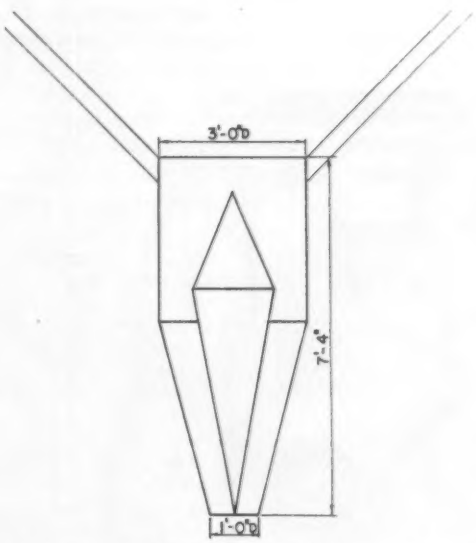

Fig. 3 The BCR easy-flow bin is a device that is added to the bottom of a bin. A large top opening, which encourages flow, is reduced to a small bottom opening suitable for delivery to a material handling device. The inverted and upright cone combination in the center causes flow to occur from the outside of the 3 ft, 0 in. *D* upper opening and this is expanding flow

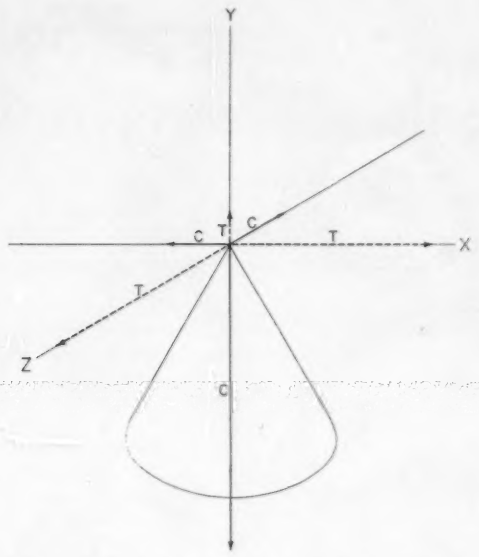

Fig. 4 The strength properties of fibrous materials are shown on orthogonal coordinates. Tension is shown as a broken line with positive direction and compression as a solid line with negative direction. The position a vertically penetrating cone occupies is shown in relation to these coordinates

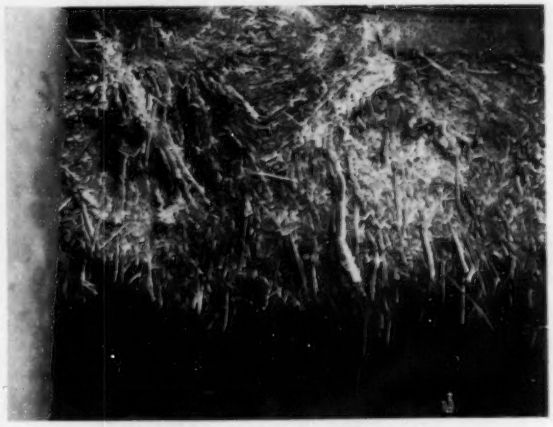

Fig. 5 When silage is suspended by a series of baffles around the bottom of a silo, a restriction is created that allows relief between the baffles. The baffles are located in the top left and right corners. The resulting radial fracture is located on a vertical line in the center. Note the downward ballooning of the fibers and their complete separation

It has been demonstrated that the potential energy contained in a stored mass of fibrous material is insufficient to cause it to separate and divide when pierced by a vertically penetrating cone (5). This means that the method used to encourage granular materials to flow, movement over an expanding surface, cannot be used for fibrous materials. In storage, fibrous materials are laminated horizontally and have great strength in tension in the X and Z directions, and in compression in the Y direction (Fig. 4). It is weak in tension in the Y direction and in compression in the X and Z directions. The cone's penetration is opposed by all three strengths.

If the diameter of the opening in the bottom of a silo through which the material moves were the same diameter as the silo, plug flow would occur. Even if a design of this kind could be created, it is impractical since the material remains in bulk with the same dimensions and strength characteristics. When the diameter of the bottom opening is made slightly smaller than the diameter of the silo, compressive forces are applied to the material as it moves through the opening. Since the material is weak in compression, it fractures and breaks while adjusting its dimensions to flow through the restriction. When the restriction is composed of intermittent baffles, circumferential compression with relief between the baffles enables the material to fracture radially (Fig. 5). This is in addition to the circumferential fractures caused by diametral compression.

It is conceived that, if the flow through the restriction were properly controlled, a hopper could be used to collect the material and direct it into a conveyor. Of greater value, though, is to have the silage from a silo fall into a feeding manger so that it can be consumed easily by cattle, or use the partial support and fracturing of the material to enable a mechanical bottom unloader to remove material from the silo easily. Compression in the horizontal plane and tension in the vertical direction are the weak properties to exploit when handling fibrous materials.

To be certain that fibrous materials will respond as described, the storage must be filled properly. The material should be applied uniformly to as large a surface area as possible. Since most filling is accomplished by means of an intermittent or continuous stream that is confined, for example, discharge from a blower or elevator, it is better to apply the stream to the periphery of the storage than to a smaller area in the center. Peripheral distribution increases the surface area of application greatly. It also reduces the volume filled by flow from the deposited material since flow is toward the center.

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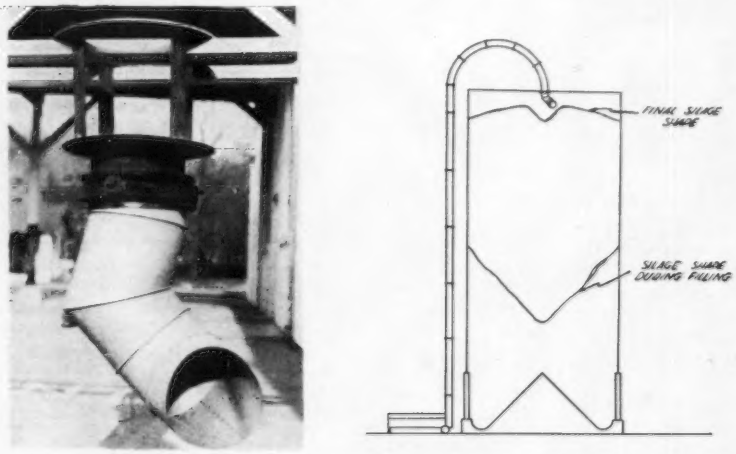

Fig. 6 A reaction type distributor that applies a material to the periphery of the storage is shown. *(Left)* The upper section is stationary, the lower section is bearing mounted and rotates under the influence of the air and material passing through it. *(Right)* Silage shape at the top of the mass during filling is an inverted cone. Center fill occurs by flow over a contracting surface. The final silage shape is created by the trajectory of the material from the outlet of the distributor

Liquid Materials:

Materials Handling Applied to Milking Operations on Dairy Farms

W. E. Shiffermiller
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Engineering tools offer effective means for improvement in materials-handling methods and equipment used in the milking operation

THE shortage of farm help and the subsequent higher cost of labor since World War II, together with the trend toward much larger milk production per farm, has given a great impetus to improved materials handling in producing milk on dairy farms.

The improvement of methods of materials handling of milk on the farm lends itself very well to the effective engineering tools of work simplification analysis, time and motion studies, and work place layout. The application of these tools should be the starting point of any study aimed at better milk handling.

Many different methods are used on dairy farms, but regardless of the method or the work place layout, the operation should be broken down into its basic elements, and all of these elements systematically listed. Time studies should then be made to establish time requirements for each element.

In all economic comparisons of alternate milk-handling methods the use of time and motion studies are invaluable. Man and machine charts are also very effective in determining the correct balance between the number of milking machines and available man power.

The handling of milk on the farm is adaptable to many of the principles of materials handling as applied to fluids, but it has two major factors that need to be given special consideration:

1 Sanitary and physical requirements of market milk

2 The cow's udder as a container which makes materials handling of milk a function of the movement of a living animal, and the movement and subsequent removal of milk from the animal must not harm her physical well-being.

Milk as a complex biological fluid comes under various municipal, state, and federal regulatory agencies which rigidly prescribe the conditions under which it may be handled. Variations from these standards may affect its bacteriological or physical make-up which can affect its marketability. Materials handling of milk must therefore be confined to operations that comply with these standards.

The factor of a living, self-motivating container as found in the cow's udder is unique in materials-handling practice. This factor has played an important part in recent rather revolutionary developments in materials handling of milk.

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Two basic classes of equipment used in moving milk on the farm are (1) containers and (2) pipes and tubes. A list of the most common types in these two categories is as follows:

Containers — Milking pails, 5, 8 and 10-gal milk cans, holding and cooling tanks, and pickup tank trucks

Pipes and Tubes — Stainless steel pipe, glass pipe, plastic tubing, sanitary valves, pumps, in-line metering and weighing devices

The different methods of milk handling can be classified into three broad categories as follows: Can system, bulk-tank system, and pipe-line system. There are many variations of these systems and parts of each may be found in the others.

The Can System

The can system is as old as the dairy industry, and although its use is declining, it is still widely used in many areas. In general, the can system consists of milking the cows by hand or machine, the transferring of the milk to milk cans, the movement of the cans to a can cooler, and the removal of the cans from the cooler and loading on a can hauling truck for delivery to the market.

The principal movements in this system are:

1 Movement of empty and full cans to and from the milking area

2 The placing of the full cans in can cooler

3 The removal of the full cans from the can cooler

4 Movement of the full cans to the pickup can truck

5 Loading the full cans on the pickup truck.

During the long period in which the can system was the only method in use, the great majority of farms used very little materials-handling equipment and cans were handled by heavy manual lifting. There were, however, some isolated instances of good materials-handling practices utilizing equipment that was available and applicable at the time. The development of alternate revolutionary concepts prevented the widespread application of materials-handling equipment to the can system.

There is today much materials-handling equipment that applies to the can system, but the initial cost of some of it prohibits its use considering the limited time it can be used. Movement of the cans can be divided into horizontal and vertical movements, and materials-handling equipment that is practical include:

Horizontal movements—Two-wheel and four-wheel hand trucks, roller can conveyor, and industrial fork-lift trucks

Vertical movements—Industrial fork-lift trucks, mechanical can lifters, winch-type can lifts, and hydraulic platform lifts

. . . Milk Handling

The most common type of handling equipment used in can operations is the two-wheel hand truck. It is used in the movement of full and empty cans to and from the milking area, and to and from the pickup truck. It is manufactured in a variety of types, the most effective of which is the one that picks up the can by the handle, thus eliminating manual movement of the can. The number of cans capacity usually varies from one to four cans. The four-can type will substantially reduce the walking distances.

The four-wheel can truck is also widely used. It is available in various capacities from two cans to ten or more. It serves the same horizontal movements as the two-wheel hand truck. In many installations it is capable of reducing walking time over the two-wheel type due to its greater capacity.

A roller can conveyor can be effectively used in horizontal movements in the can system. It is particularly useful in moving full and empty cans to and from the milkhouse and the pickup truck. The establishment of correct elevations of the milkhouse enables loading and unloading of full and empty cans at the pickup truck without the heavy lifting.

The development of the fork-lift industrial truck in materials handling has been rapid in the last decade. These trucks are now manufactured in many types, and with their ingenious attachments they are adaptable to many industrial materials. They vary from simple low-cost types to complex and relatively expensive machines. There has not been very extensive use of these trucks in can handling on the farm. However, in all probability, there would have been more widespread use of them had not the development of simple, low-cost lift trucks coincided with the large-scale replacement of the can system. Strictly from an ease of handling standpoint the type of industrial truck that would be most desirable would be the powered riding type, but the original cost of this type machine would probably prohibit its use in farm can handling, except on the very large dairy farms and in cases where other farm materials handling could utilize the truck when not in use in can handling. The type of truck that does have economical application to farm can handling is the walking type that is powered for vertical movement only. For horizontal movement it would replace the two and four-wheel hand trucks and also be available for all vertical movements.

Vertical movements of cans in the can system are involved in transferring the cans in and out of the can cooler, and the loading and unloading of full and empty cans at the pickup truck.

The can cooler is an important factor in the materials handling of cans. These coolers range from simple homemade cement tanks to modern large capacity mechanically refrigerated cabinets. The elevation of these coolers and whether they have top or side openings for loading affect the handling of the cans.

There are a number of materials-handling devices available to facilitate the vertical movement of cans in and out of these coolers. The fork-lift truck with powered vertical movement is effective in this operation. The winch-type lift offers a low cost, but relatively slow, method of handling this movement. The use of simple hydraulic lifts, many of them homemade, offers a fast and economical method for this movement.

The movement of the full cans into the pickup truck has historically been one of back-breaking physical effort, but with practically no effort being made to develop better handling methods. The freight trucking industry has in the last fifteen years developed a series of hydraulic platforms that have been very effective in solving the movement of material from ground level to truck bed elevations. These hydraulic platforms have been of various types and sizes, with some of them located outside the body and others are cut out of the truck bed itself. They utilize both rear and side loading. There has been some use of this equipment on can pickup trucks, and it offers an economical and effective method of eliminating the heavy manual lifting of cans.

In summary, it can be said that there is available today materials-handling equipment that is applicable to the effective and economical handling of materials in the can system, and the use of this equipment, in conjunction with an efficient work place layout, can result in greatly improved can-handling efficiency.

The Bulk-Tank System

The past ten years has seen the development of a radical departure from conventional can handling of milk in the bulk tank system. The system consists of milking by hand or with a milking machine, the movement of the milk in cans or by pipe line to the cooling tank, the utilization of a stainless steel tank as the storage container, the utilization of mechanical refrigeration applied to the walls of the tank for cooling, and the transferring of the milk by pump to a bulk pickup over the road stainless steel tanker. The significance of this development from a materials handling standpoint was the elimination of the can as a storing and movement to market vehicle. In addition this development had a direct effect on materials-handling methods at the processing plant. Probably the greatest effect of the new system was a substantial improvement in the quality of raw milk delivered to the processing plant.

The movement of the milk from the milking area to the storage tank in the bulk system, when not used in connection with pipelines, is the same as in the can system. The most common method is the use of the two and four-wheel hand trucks. Milking machine setups are available which allow the flow of milk to go from the milking machines to a series of cans which can be disconnected as they are filled without disturbing the continuance of the milking operation.

A vertical movement of the cans is required at the storage tank, which consists of lifting and pouring the milk through an opening in the top of the tank. Materials-handling equipment and methods that are available to handle this movement are (1) placing the storage tank at a lower elevation to minimize the distance lifted, (2) use of a simple ramp alongside of the tank, (3) hydraulic can lifters and dumpers, and (4) winch-type can lifts.

Materials handling in the bulk system must provide provisions for determining accurately the weight of each shipment of milk. The most common methods for accomplishing this are (1) calibrating the tank and measuring with a dip stick, (2) flow meters, (3) in-line weighing devices, and (4) placing the bulk tanks on platform scales.

The most widely used method is the use of the dip stick, and while it has a number of deficiencies, it is probably the best that is available at the present time when consideration is given to cost and relative accuracy. There has been much accomplished recently on the development of sanitary flow meters and in-line weighing devices, and in all probability the future will find equipment of this type that is available at reasonable cost and with satisfactory accuracy.

There has been some use of placing the bulk tank on a platform scale. This method, if set up correctly, probably offers the most accurate system for weighing in the bulk method. It does, however, have a relatively high initial cost.

The bulk tanks are available in various sizes, depending on the amount of milk produced. The size of the tank is a factor in materials-handling efficiency relative to the practice of every-other-day pickup which has effected some reduction in handling costs.

The final movement of milk from the bulk tank to the pickup tanker is accomplished by a pump located on the

pickup truck, which pumps the milk through a flexible sanitary hose.

The Pipe-Line System

There were a number of isolated applications of moving milk through pipe lines in relation to farm milking operations during the 1920's, but the development of the bulk-tank system opened up the real potential of this system as a widespread method for the improved handling of milk on the farm.

The pipe-line method consists of a system of pipe lines which carries the milk from the milking machines to the bulk tank in a continuous flow. The pipe material is usually stainless steel or glass, varying in size from one to two inches in diameter. The relatively recent development of a system of cleaning these pipe lines in place by the circulating of cleaning solutions through them greatly improved the effectiveness of the pipe-line system as a milk-carrying method. Before the development of this cleaning method, the pipe lines had to be completely disassembled for cleaning, which was a time-consuming operation.

From a materials-handling standpoint the pipe-line system eliminates the movement of the milk in cans from the milking area to the bulk tank and the vertical movement into the bulk tank.

In all the milking systems the layout of the work place area is of very great importance, and in the pipe-line system it makes possible an approach to a completely automated milking operation. It is here that full utilization is made of the self-movement of the cow as a materials-handling aid. In general, these layouts can be classified as (1) a stanchion type and (2) milking parlor type.

In the stanchion type, the most common layout is to utilize two parallel rows with a work space in between. The pipe line is then constructed overhead with connections to the milking machines. In general, all of the cows to be milked are brought in at the same time and all remain until the milking is completed.

One of the most revolutionary steps in the materials handling of milk has been the relatively recent development of the milking parlor in connection with the pipe-line and bulk-tank systems. There are a large number of different types of these parlors, and variations within the types, but for the most part they can be classified as follows: Stanchion type, 4-cow tandem walk-through type, 8-cow tandem walk-through type, swivel-chair type, and New Zealand type.

All the systems utilize a loafing area and make use of the cow's willingness to move in and out of the milking position. The construction of these parlors vary in their elaborateness, but all are of sanitary construction.

The stanchion type is the simplest type and uses an ordinary stanchion layout with space for 4 to 8 cows.

The walk-through types consist of units of four cows, two on a side, with a pit working area between. Moveable feeding arrangements are provided. Two milking units are used with two cows being milked at a time, and the other two cows being prepared for milking. The man-power requirements for this unit is one man.

The swivel-chair type, in general, uses two cows side by side with a swivel chair, for the operator to sit on, in between. One milking unit is used with one cow being milked while the other is being prepared. A system of chain linkages and pulleys are utilized to open and close doors, and activate feed chutes thus making it possible for the operator to perform the entire milking operation without leaving his chair.

The New Zealand system is made up of two rows of stanchions of six on a side with a pit working area in between. The cows are brought in in groups and nested six on a side at a 30-deg angle. Six milking units are used with six cows being milked at a time with the other six being prepared. It is claimed that in many cases one man is able to operate this unit. There are a number of modifications of this system with more or less cows on each side, and utilizing more or less number of milking machines.

Regardless of the type of pipe-line milking-parlor systems they are all aimed at streamlining the milking operation. On the large dairy farms they have enabled the milking of large numbers of cows with a minimum of man power in a total time that would be impossible with older methods.

The measure of their efficiency has, by common usage, been established as a certain number of cows per hour. The trade press, in recent years, has carried numerous articles citing outstanding milking speeds. The phrase "a cow a minute" is a common one in describing these operations. The first claims of this speed were established with two-man operation, but recent claims cite examples of accomplishing this speed with one man. In any event, these systems have certainly accomplished a lot in improving the materials handling of milk.

Cleanup Operations

Due to the rigid sanitary requirements under which milk must be handled, the cleanup of all materials-handling equipment must be considered as part of the overall materials-handling problem. This in materials-handling parlance is the "make ready" phase of an operation. In any comparison of alternate materials-handling methods the time required for cleanup must be given full consideration.

Under the old take-down system, the cost of the pipe-line method would be prohibitive. But fortunately the development of cleaned-in-place procedures makes it possible to get entirely satisfactory cleaning without disassembling the pipe lines.

These cleaned-in-place systems for pipe-line layouts vary from simple manually controlled cleaning solution circulation, to complete push button systems utilizing interval timers for complete automatic cleaning of the pipe lines, the milking machine, and the bulk tank.

Economic Factors

The scope of this paper does not permit a detailed analysis of all the economic factors relative to comparisons of alternate methods of materials handling of milk on the farm. The many variables that exist on dairy farms, such as the volume of milk produced, the existing physical facilities, etc., suggests an individual analysis for each farm. In any event, a complete engineering economic analysis should be made before adopting a changed materials-handling system. This analysis should consider the following factors:

1 The economics of the milking operation must be considered only as a part of the overall farm operation. Man power savings resulting from improved materials-handling methods are only effective, in the true economic sense, if this man power is utilized elsewhere.

2 The reasons for improved materials handling of milk are to improve quality, to reduce the cost of milk production, and to reduce the physical work of man.

The economic value of the reduction in the direct and indirect costs of milk production by alternate materials-handling methods is relatively easy to establish by a complete analysis. The improvement of quality, although of unquestioned economic value, is much more difficult to place a dollar and cents value upon. The reduction in the physical work of man, without regard to the successful use of this time in other productive effort, is also of a somewhat intangible value from a dollar and cents standpoint. To the extent that reduced work loads enable the procurement of better workmen, then dollar values can be assigned to this factor. Another intangible factor is leisure time provided by improved materials handling for one-man owner operated farms. In this case the owner may

(Continued on page 561)

Engineering Principles in Handling Liquid Materials

- Fertilizers
- Feeds
- Pesticides
- Nematocides
- Liquid Manure

C. M. Hansen
Member ASAE

SUCCESSFUL handling of liquid agricultural chemicals depends largely upon the properties of the chemical, the time of handling, and the quantities to be moved. Many chemicals now in common industrial usage are relatively new to the farm. Anhydrous ammonia for direct application, herbicides, nematocides, and many of the other pesticides have only come into common usage since World War II. The advantages of the new chemicals usually become known long before adequate means of hauling, transferring and metering them to the soil are developed.

Handling Anhydrous Ammonia

The properties of anhydrous ammonia require that it have special handling. Ammonia is a highly volatile material and should be handled with utmost care. All the necessary precautions in the handling of this material should be learned before an operator begins work with any type of transfer equipment.

The vapor pressure of anhydrous ammonia at 100 F is 197.4 psi, and at 75 F it is 126.8 psi. The density of the material also varies greatly with the temperature. It weighs 39.9 lb per cu ft at 32 F and decreases to 36.4 lb per cu ft at 100 F. Other characteristics peculiar to this material also make it difficult to handle. A considerable drop in pressure occurs in the transfer lines. Hedman(2)* and Turner's calculations from the Bureau of Standards circular No. 142 show that a pressure line drop of from 2 to 5 psi will occur between the tank and a metering device. This drop depends upon the application rate. The lower pressure drop of 2 psi occurs with a tank pressure of 50 psi, giving a vaporization of 0.313 percent. This causes a reduction of density from 39.8 lb per cu ft in the tank to 24.4 lb per cu ft in the line.

Anhydrous ammonia is detrimental to zinc coatings, and to copper and its alloys, as well as to numerous forms of aluminum. It can be readily handled in steel containers. Specially designed reinforced rubber hose is used wherever flexible transfer lines are desired. The American Standards Testing Materials has established that vessels should have a working pressure of 250 psi. Many states also have regulations governing the handling of this chemical. H. T. Barr of L.S.U., at the ASAE meeting in Roanoke, Va., in 1956, reported on the work being done in Louisiana to establish testing techniques for tanks, hose, fittings, and meters for anhydrous ammonia.

Ammonia in the bulk form for agricultural use is usually transferred from the railroad tank car or truck to the dealer's bulk plant by a vapor return system. This system uses a refrigeration type ammonia compressor to reduce pressure in the storage vessel by pumping its vapors into the vessel to be unloaded. Such a system allows ammonia to flow freely into the storage vessel. After the liquids have been transferred, a slight vacuum is put on the empty tank to transfer as much of the vapors as possible. Either the vapor return system or a vapor bleeding system is used to transfer ammonia from the bulk storage tank to the portable "nurse" tank. In the vapor bleeding systems, opening a small vent causes a rapid expansion of the ammonia, reducing the temperature and pressure of the receiving tank. This system can cause as much as a 10-percent loss of ammonia. The vent valve used for bleeding is usually attached to a tube extending into the tank for indicating an 80-percent fill of liquid. This precaution is taken to allow for expansion in case the temperature rises after the ammonia has been put into the tank.

A transfer unit that works on the principle of expanding gases has been developed to transfer the ammonia from the nurse tank into the applicator tank. This device reduces losses to a minimum. However, the common technique for transferring ammonia from the nurse tank to the applicator tank still is the bleeding method.

Metering Anhydrous Ammonia

There are several factors to consider when metering any of the liquid fertilizers to the soil. They are: *(a)* rate of application per acre, *(b)* width of swath made by the applicator, *(c)* speed of applicator, *(d)* pressure or head of chemical to be applied, *(e)* orifice size through which chemical is metered.

The most common technique used to meter anhydrous ammonia from the applicator tank to the soil employs the pressure differential system. This system takes advantage of the high ammonia vapor pressure. It requires that a constant pressure differential be held across an orifice (Fig. 1). This system may have a slight flow rate error caused by changes in ambient air temperature, and by such variables as speed of applicator and differences in soil from one part of the field to another (Fig. 2).

Several manufacturers who make this metering system use a graduated needle valve. The field operator can set the valve at a desired rate of application. (The operator must know the speed of the tractor and the quantity and the size of the orifices.) Orifices are located either in a manifold near the flow regulator or in the applicator feet. It is imperative, however, that the length of hose leading from the manifold to the injection blades be kept constant.

Another system for metering anhydrous ammonia makes use of a pump geared to a ground-driven wheel (Fig. 3). Such a system merely restricts the flow and eliminates the speed variable.

The most common type of metering pump is a single-cylinder, variable-length stroke unit that may be driven by the tractor or implement wheel. This system—as well as the differential pressure system—will pass about 1,000 lb per hr. This is equal to about 200 lb per acre for a 10-ft applicator traveling at a speed of 4 mph. It is essential that a heat exchanger be used with the ground-driven metering pump to minimize the reduction in fluid density of the chemical from the tank to the pump. The expansion of the chemical after it leaves the pump "chills" the ammonia in the line between the tank and pump.

It might be well to mention here that the use of the heat

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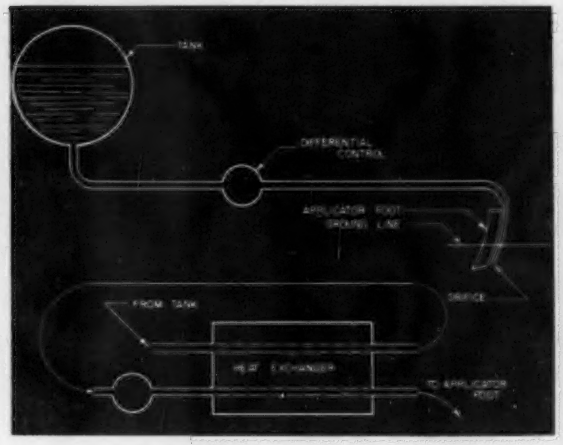
*Numbers in parentheses refer to the appended references.



Figs. 1 and 2 *(at left)* Differential control systems for metering NH_3 to the soil. The heat exchanger can be used to reduce density differences of the ammonia between tank and metering device

exchanger will also improve the performance of the differential pressure system.

Limited research has been conducted with high pressure pumps to disburse the ammonia into soil at higher than vapor pressure. More work is necessary in this field.

A third system of metering anhydrous ammonia makes use of the rotameter (Fig. 4). Certain necessary precautions should be observed if a glass tube is used in the rotameter. The steel-tube, magnetic follower rotameter is more expensive but less hazardous to use. It is necessary to use a heat exchanger with a rotameter to eliminate vapor bubbles passing through the rotameter. The expansion of the ammonia that takes place at the variable orifice will cause it to chill to a more constant density before it passes through the rotameter.

Research(5) shows that one efficient method of applying NH_3 directly to the soil employs a moldboard or disk plow (Fig. 5). Such an operation makes use of minimum tillage methods to take full advantage of the greatest economy of application.

Aqua Ammonia

A 22-percent nitrogen aqua ammonia solution will have very little vapor pressure at 90 F. It will have no vapor pressure at temperatures below 89 F. Less costly equipment can be used to handle ammonia in this form. It, however, must still be released below the surface of the soil. A primary deterrent to this system is the added freight cost from the added weight of the water. With 22-percent nitrogen, the amount of water is 73 percent. Aluminum, steel, stainless steel, and a number of the plastics are not affected adversely by this material.

Aqua ammonia is used principally in California, where it is compounded at a local plant and delivered to the farmer in much the same way as gasoline. In some areas, the aqua ammonia is picked up by the farmer in a tank wagon or tank truck. Transfer of the chemical is accomplished by motor or engine-driven centrifugal pumps. The tendency is toward larger transfer lines—2½ to 3-in. inside diameter—in an effort to reduce the down time of the application equipment.

The depth of application for aqua ammonia should be kept below 4 in., and care must be taken to insure immediate closing behind the applicator foot. Tests conducted by Hansen and Robertson(4) indicate that losses can be as high as 1.7 percent of total nitrogen applied when the ammonia compounded nitrogen is released at a depth of 2 in. below the soil surface.

Applying Liquid Fertilizer

Several variables must be considered to obtain the desired application rate when metering liquid fertilizers to the soil. They are: *(a)* speed of the applicator, *(b)* width of the appli-

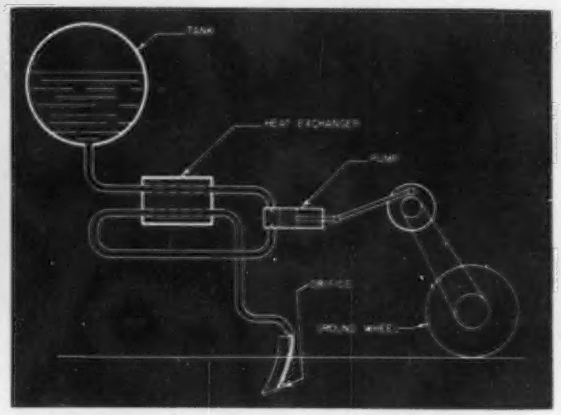


Fig. 3 A ground-wheel-driven, variable-length-stroke pump for metering NH_3 to soil

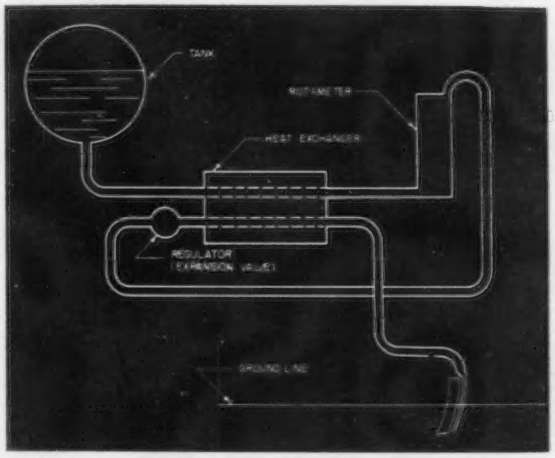


Fig. 4 The rotameter can be used to note visibly the hourly flow rate of NH_3. A heat exchanger must be used with this system

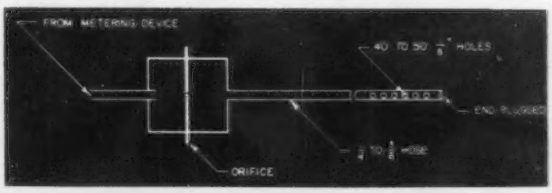


Fig. 5 Hoses having an inside diameter of ¼ to ⅜-in can be used to "plow down" NH_3. The several holes in the side of hose near the end result in a more efficient application than a single large hole

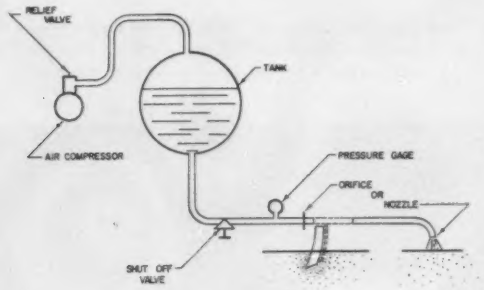


Fig. 6 An air compressor used to maintain a constant head in metering liquid fertilizers

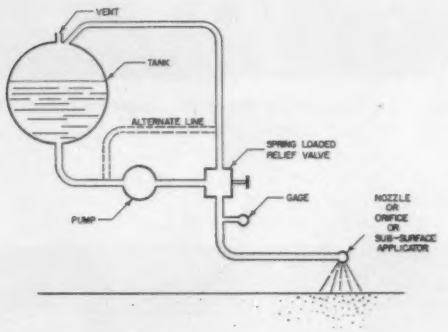


Fig. 7 The hydraulic system common to weed sprayers can be used to apply certain liquid fertilizers and nematocides

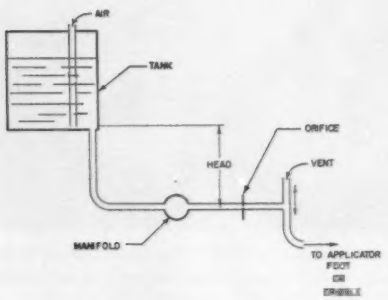


Fig. 8 A tank mounted on the applicator to give sufficient head to accurately meter liquids

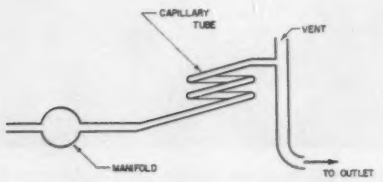


Fig. 9 The capillary tube used to control flow rate in the gravity system of metering liquids

. . . Liquid Materials

cator or nozzle spacing, *(c)* the size of the orifice, *(d)* the head of the chemical at the orifice. The four systems of metering a liquid fertilizer are:

(1) *Pneumatic*—The chemical is placed in an airtight container that will withstand the working pressure. A constant head on the chemical is obtained by an air compressor. The chemical is forced out through orifices in the applicator feet or nozzles. It is possible to use a manifold that incorporates a device to give a uniformly variable orifice size leading to each one of the applicator feet or openings (Fig. 6). One manufacturer markets such a device with eleven openings. It receives the liquid from a single line within a range of pressures and flow rates. The "flow-divider" will give equal flow to the eleven lines through precisely machined variable orifices controlled by a single spring. This unit will function satisfactorily where outlet pressures are low. A spring-loaded relief valve on the air compressor maintains the constant head. A more precise method of observing the flow rate of the chemical can be had by adding a rotameter in the liquid line.

(2) *Hydraulic*—The chemical is pressurized to a constant head by a pump. Piston, gear, roller impeller, etc. pumps may be powered by the power take-off of the tractor or a gasoline engine (Fig. 7). A pressure relief valve, which returns a portion of the liquid from the pump back to the tank or the intake side of the pump, maintains the constant desired head. Orifice plates mounted in a manifold feed the applicator feet. Some manufacturers place the orifice face plates near the extreme outlet. Needless to say, orifice plates are not used when the chemical is forced through spray nozzles. Here again a rotameter might be used in the line if a more accurate reading of a flow rate is desired. The flow-divider may also be used with this system.

(3) *Gravity Flow*—The third system takes advantage of the head that can be obtained by the fall of the chemical from the applicator tank to the soil. Three types have the tank mounted high on the machine. One type places the orifices at the outlet. All lines leading from the tank should be of equal length and size. The falling head of the chemical in the tank, however, will cause a variation in the flow, but many users feel that this error is compatible with other variables in crop production. A more constant head can be had by sealing the tank and inducing the air at the bottom of the liquid (Fig. 8). Different application rates can be had by changing the orifice size or the speed of the applicator.

A refinement of the gravity flow principle can be had by leading the chemical from the bottom of the tank to a manifold (Fig. 8). Orifice plates are mounted in the manifold to feed the outlets. Lines are vented next to the orifice plates. The head is then the distance between the orifice plate and the point at which the air enters the liquid in the tank. The vacuum in the tank offsets the head of the liquid in the tank above the air entry point. The head can be readily varied by raising or lowering the manifold. The application rate per acre can be changed by varying the size of orifice plates, speed of applicator, or by changing the height of the manifold with respect to the tank. Lines leading from the vented orifice plate to the outlet or applicator feet must have a gradual slope without any sags to trap the chemical. These lines must be large enough to eliminate any capillary action, but they need not be of equal length. Copper tubes of varying size and length can be substituted for the orifice plates to control the flow rate (Fig. 9). Only copper tubes will have the desired tolerances for these capillary tubes.

Another version of the gravity flow principle makes use of a "float" chamber below the level of the open tank (Fig. 10). The liquid flows from the float chamber to the manifold containing the orifice plates or capillary tubes. The manifold is in a fixed position, but the float chamber can be raised or lowered to vary the head.

(4) *Ground Wheel*—Another method uses a "squeeze" hose pump powered by a ground wheel (Fig. 11). This pump will not give sufficient pressure to atomize the chemical through the spray nozzle. The pump is mounted below the level of the applicator tank. The liquid flows from the tank to a manifold to which any desired number of hoses are attached. The hoses are stretched over a reel which is powered by the ground wheel. The action of the reel against the rubber or plastic hoses regulates the flow to the hose outlets. A refinement of this principle employs a curve block to back up the rubber hoses, eliminating need for tension on the individual hoses. This metering device can supply the chemical to applicator shanks or dribble it on the surface of the soil.

Another version of the ground-driven metering device employs a variable-stroke piston or plunger pump (Fig. 12). This pump handles any of the free ammonia solutions. It can be used to spray urea solutions on the soil surface or to apply any of the chemicals through applicator shanks below the soil surface.

Some difficulty has been encountered in metering free ammonia solutions with the hydraulic principle when using cen-

trifugal, roller impeller, or gear pumps. This difficulty occurs when the ambient air temperature goes above 70 F. Ammonia gas bubbles are forced into the lines causing erratic flow.

Nitrogen solutions that do not contain free ammonia can be applied to the soil surface by any of the above systems.

Complete Liquid Fertilizers

Handling complete fertilizers in liquid form is possible with any of the systems used for aqua ammonia or nitrogen solutions. But several precautions must be observed. The complete fertilizer solution contains nitrogen (N), and phosphoric acid (P_2O_5), and potash (K_2O), which is considered, in most cases, a neutral solution. A number of dealers are now handling the complete liquid fertilizer in mild steel containers. They report that a certain degree of etching does occur, but they can replace these tanks and lines more economically than they can purchase more expensive ones of stainless steel.

Considerable research has been conducted on the matter of coating mild steel to protect it from the damaging effect of fertilizers. Some factories have applied plastic coatings, either baked or air dried, successfully. Extreme care must be taken in applying coating—a small uncoated surface can make any coating worthless.

One of the primary considerations in the application of a complete fertilizer has to do with the "tie-up" of the phosphorous in the soil. Research data indicates that the optimum placement of liquid fertilizer is in a band below the surface of the soil. Such an application causes a concentration of fertilizer phosphorous (P_2O_5) that results in a higher availability of the plant nutrients. It follows that dribbling fertilizer phosphorous on the soil surface in bands a few inches apart could accomplish the same results.

Transferring a complete liquid fertilizer from the bulk tank to the farmer's nurse tank mounted on a truck or trailer is usually accomplished by increasing the pressure in the bulk tank with an air compressor. The air compressor has also been used to move the chemical from the nurse tank to the applicator tank. Some dealers use centrifugal pumps successfully. Others using the roller impeller or gear pump have encountered difficulty, particularly where solid salts have been formed in the liquid due to diminishing temperatures.

All four basic principles of metering liquid fertilizers have been employed in applying this chemical to the soil.

Pesticides

The problem of controlling insects, fungi, and diseases in crops has long been with the farmer. For a number of years he has relied upon the piston or plunger pump to maintain a head on the pesticide to force it through a nozzle and onto the crop. This system might be referred to as the hydraulic method, for it relies entirely upon water as a carrier to treat the crop.

In recent years, a new technique of supplanting a part of the water with air has been employed. These "air-blast" sprayers are often called concentrate sprayers. The piston pump on the air blast sprayer may be replaced with a centrifugal or roller impeller pump, since the higher head on the chemical is no longer desired. Concentrations of 10x solutions have been used in the west. The common concentration through the middle west fruit areas is a 4x solution. The obvious reason for the differences in concentration is largely due to the differences in pesticide problems. Higher concentrations reduce the quantity of water required with the application of any chemical. Reduction of the quantity of water desired minimizes a materials handling problem.

The air blast sprayer is not limited to orchards. It is now used on row crops. Farmers have learned that the judicious use of such a machine will reduce the time for applying any chemical.

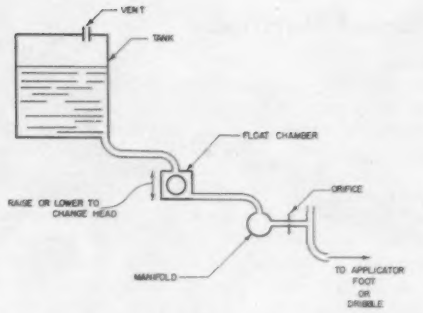


Fig. 10 A float chamber added to the gravity flow system of metering makes it possible to fix permanently the height of the manifold

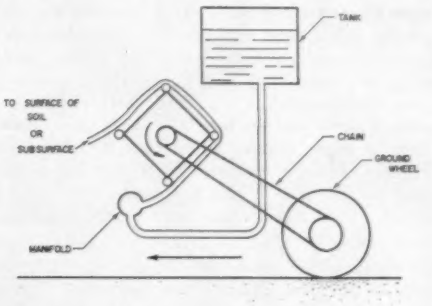


Fig. 11 The "squeeze" or "hose" pump eliminates the speed of the applicator as a variable in metering certain chemicals to the soil

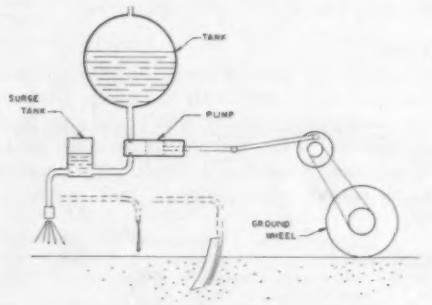


Fig. 12 The ground-wheel driven piston pump used to accurately apply chemicals as a spray, dribble or subsurface treatment

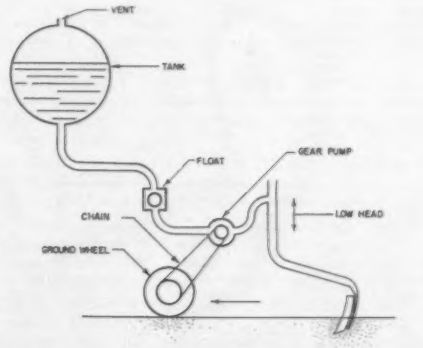


Fig. 13 Fumigants or nematocides applied with ground-driven gear pump

. . . Liquid Materials

Herbicides

The principles used in handling herbicides are quite allied to those for spraying liquid fertilizers. The chief difference is that a cheaper machine can be used because most herbicides are completely water soluble, and are not very corrosive.

Soil Fumigants

Most soil fumigants or nematocides have very little surface tension and are highly penetrating. Extreme precaution must be observed in the handling of the more volatile materials. It is not advisable to use pneumatic systems in applying them. The more volatile fumigants should be applied with gravity flow metering systems. Others might be applied with hydraulic systems such as were discussed in the handling of liquid fertilizer (See Table 1).

A most successful hydraulic pump for handling soil fumigants has the nylon roller impeller. One manufacturer is producing a nematocide metering device that makes use of close tolerance gear pumps. The gear pump is driven by a ground wheel and works against a low head. Several gears, usually eight, mesh together and are held in a single case. Each of the gears feeds a single injector blade. Air is induced into the bottom of the chemical container. The chemical flows to the gear pump, which raises it to a low head. The line is vented at this point. The liquid then flows to the applicator foot (Fig. 13).

Some nematocides should be flushed from the metering equipment at the close of the day's operation. Kerosene or Stoddard solvent might be used for this purpose. In the case of the more volatile materials, an additional tank containing Stoddard solvent should be fed into the metering system by a selector valve. This permits the operator to check the flow of the chemical as well as to flush the apparatus.

Liquid Feeds

Some interest has been shown in liquefying feed supplements for dairy cattle, beef cattle and sheep. These supplements are usually compounded with a molasses base; and, therefore, handling of this mixture will be much the same as handling molasses. Ethanol is a supplement frequently used to reduce the viscosity of the material.

Liquid Manure

Liquid manure is reappearing on the U.S. farm, but in a little different form. I can recall the large cement cistern that was used to store the liquid portions of the manure on our dairy farm in Michigan. It was broken up and filled in when I was still a small boy.

No doubt many can recall the early research conducted at experiment stations in the midwest on the handling and use of gutter liquids from dairy farms. Primary reason for discontinuing such practices is largely due to the lack of sufficient equipment to handle the material without backbreaking labor. Another factor that brought about the discontinuance of handling the urine separately is that it solved only a portion of the manure handling problem.

Mixing the solids with the liquid manure and adding a little more water is not a new practice in our modern day agriculture. Many farms in Germany liquefy the solids with additional water and pump them through an overhead irrigation system out over the farm. It is doubtful that such a practice would meet with favor on our American farms, particularly in the north, for temperatures are below freezing a greater portion of the year. Those who have observed such operation in Germany report that the countryside is filled with a disagreeable odor, particularly during the application period.

Only a few agricultural experiment stations are engaged in research on the handling of liquid manures. Very little conclusive data is available at this time. It is only possible to report what is being done on a few farms throughout the United States.

The average dairy cow consumes between 12 and 15 gal of water per day. About 56 percent of this is excreted in the feces, 13 percent in the urine, and the remaining 31 percent either remains with the cow or is lost by oxidation. These figures would also apply to beef cattle. From this information, it is reasonable to assume that only a portion of the livestock living area could be flushed with water. In the case of dairy cattle, perhaps a farmer would be able to flush only the holding and milking areas to liquefy the manure. With beef cattle, perhaps only the feeding area would be flushed. On some farms solids are simply scraped into a gutter. The material is then flushed into an open irrigation ditch or a holding tank. The surface may or may not then be flushed clean. The method reduces the quantity of water required to move

TABLE 1 SYSTEMS FOR APPLYING FERTILIZER SOLUTIONS

TYPE OF SYSTEM	HEAD MAINTAINED BY	POWERED BY	CONTROL OF HEAD	DISTRIBUTION SYSTEM	APPLIED TO SOIL	RATE PER ACRE GOVERNED BY	TANK VENT	SYSTEM WILL APPLY
Pneumatic	Air compressor	PTO - Engine	Relief Valves on Compressor Nozzle Orifice plate	Manifold or Flow-divider Hoses	Subsurface Surface Spray Dribble	S. O, H, OS	Sealed	All non- or low-pressure fertilizers
Hydraulic	Pump: Gear Centrifugal Roller Impeller (Others)	PTO -	Relief Valve on line Nozzle Orifice Plates	Manifold Boom Orifice Plates	Subsurface Surface Spray Dribble	S, O, H, OS	Vented	Non-pressure fertilizers. Limited solid salts in fertilizers.
Hydraulic	Variable stroke piston	Ground wheel		Manifold Flow-divider	Subsurface Surface Spray Dribble	G	Vented	All fertilizer solutions.
Gravity	Float chamber. Air induced at bottom of tank. No control.	None	Orifice Plate. Raise or Lower float chamber. Height of tank. Capillary tube.	Manifold Hoses	Dribble on surface Subsurface	S, O, or C, H, OS	Air induced at bottom of tank.	All fertilizer solutions.
Hose Pump		Ground wheel		Manifold Hoses	Dribble on surface Subsurface	G	Vented	All fertilizer solutions.

S - speed of applicator
O - orifice or nozzle size
H - head
G - ground wheel
OS - outlet spacing
C - capillary tube

the manure. The other method relies upon the water to do the entire cleaning job.

In a few hog feeding operations, when the temperature does not drop below freezing for more than a week at a time, manure has been successfully cleaned from the pens entirely by water. A more economical use of water could be had by first scraping the solids into a flushing gutter. Complete cleaning could be had by then flushing the entire area. The average hog on a fattening ration takes in about 5 lb of feed per day per 100 weight of animal. This animal will consume about twice as much water as feed by weight during this period. He will excrete through the feces and urine about 5 lb of manure per 100 weight of animal. The feces is about 75 percent water, and 40 percent total excrement is urine.

A Missouri farmer reports that on a 350-hog installation he is able to flush the weekly accumulation of solids, without prior cleaning, into a holding tank by using about 2,500 gal of water for the flushing operation. The seven pens are 26 by 55 ft, with the gutters sloping toward the holding tank. About an 0.8 percent slope is used in the gutters, with a 1.66 percent slope on the concrete toward the gutters. The 17,000 gal storage tank held the liquid during the periods when it was impossible to spread the material in the fields. This farmer is flushing with about 15 gpm at 150 psi. A centrifugal pump is used to put the solids in suspension while unloading the holding tank. A 1,000-gal tank truck is used to haul the material to the field. The liquid and solid materials are spewed on the ground through a boom having 2-in. openings about every foot. No attempt is made to control the head during the unloading operation.

A California dairy farmer reports that much time is saved in cleaning up the milking parlor area, and the holding area by flushing down the floor into an open ditch irrigation system.

Perhaps the crux in the handling of liquid manure is the type of pump required to move the manure from one area to another. All of us are familiar with the operation of centrifugal and diaphragm pumps—the stand-bys in handling abrasive liquids and semisolids. A newer pump that shows much promise is the helical rotor pump with a rubber or synthetic-rubber stator (Fig. 14). The manufacturers of this pump have demonstrated that it, too, will function under adverse conditions.

It is evident that the livestock area should be especially designed for handling liquid manure. In deciding the best system for any farm, consider the questions listed below:

- What are the economic factors involved in liquefying the manure?
- Is it possible that the farmer should destroy the soil nutrient products in the feces and urine, and purchase his fertilizer?
- What are the effects of this system on milk and meat production?
- Should the feces be handled entirely by mechanical means in the livestock area, using only the water as a clean-up medium?
- How much water is required by the several systems per head of livestock?
- What are the time requirements in the handling of livestock under the several systems?
- What disposal can be made of the liquid manure during sub-zero temperatures?
- What are the labor requirements under the several systems?
- What are the effects of the several systems of livestock management on the end product?
- What is the best structure design for handling liquid manure?

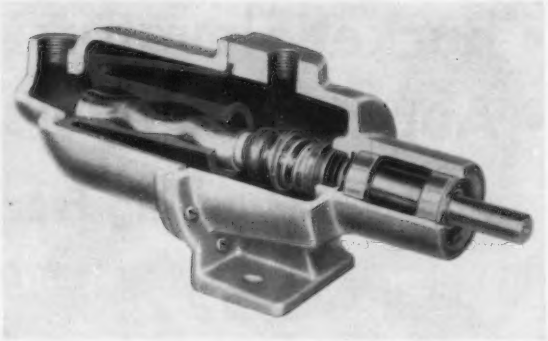


Fig. 14 The helical rotor pump can be used for handling manure in semisolid form

No doubt there are many other questions which should be answered before a recommendation can be made as to the requirements for handling liquid manure.

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• Bucket Elevators
• Auger Conveyors

For Handling Free-Flowing Materials

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THE free-flowing characteristic of small grains and pellets permits their handling by a number of different devices. In many agricultural handling and processing systems the flow plan requires both vertical and horizontal movement of the materials. Some devices, such as the screw or auger, can be used at any elevating angle. Others are best suited for vertical or horizontal operation only. Still other devices such as the chain and flight conveyor are practical at angles from horizontal to a maximum elevating angle of about 45 deg.

Bucket Elevators

The bucket elevator is the most efficient means of producing vertical movement of free-flowing materials. This device is often used in grain handling and processing systems.

The elements of a bucket elevator are:

(a) Buckets to contain the material.

(b) A belt or chain to carry the buckets and transmit the pull.

(c) A means to drive the belt or chain.

(d) Accessories for loading the buckets, receiving the discharged material, maintaining belt or chain tension, and for enclosing and protecting the elevator.

Three types of bucket elevators are suitable for elevating small grains and pellets.

The *centrifugal-discharge* bucket elevator is the most common type used in elevating free-flowing materials. Buckets are uniformly spaced on a belt or chain to prevent interference when discharging. Material is discharged by centrifugal force at the head and is picked up by direct loading into the buckets and by scooping from the boot at the foot of the elevator.

The *perfect or positive-discharge* elevator has the buckets suspended at intervals between two chains. Discharge is accomplished by two snubber sprockets located just below the head wheel. These cause the buckets to be carried towards the center of the elevator a sufficient amount to clear a discharge chute located just below the head wheel. Discharge is primarily by gravity. Pickup of material is similar to that of the centrifugal-discharge type.

Since this type does not require high speeds for discharge it is particularly suited to the handling of light, fluffy, dusty, or sticky materials that will not discharge cleanly from the centrifugal-discharge type.

The *continuous bucket* elevator consists of a continuous series of buckets attached to a belt or chain. The front of each bucket is shaped in such manner as to act as a deflector or chute for the material being discharged from the succeeding bucket as it passes over the head wheel. This method of discharge makes possible low belt or chain speeds without loss of capacity. Operating the elevator at an inclination allows placement of the discharge chute directly below the discharging buckets for cleaner operation.

A feeding leg is necessary to introduce the material two or three buckets above the center of the foot wheel. This accomplishes loading without scooping from the boot. Continuous buckets are not designed for scoop loading.

The continuous bucket elevator is commonly used for handling heavy gritty materials such as sand, coal, and ores.

Centrifugal-Discharge Elevator

The centrifugal-discharge elevator is most commonly employed for vertical movement of free-flowing materials such as small grains and pellets. The relationship between head-wheel speed and diameter is very important in the satisfactory operation of this type of elevator.

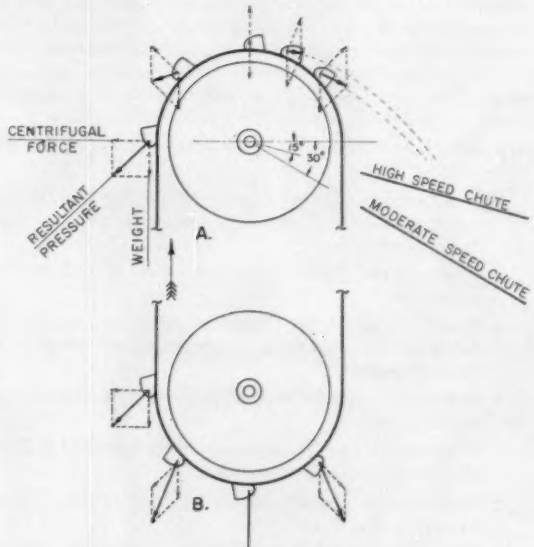

Fig. 1 *(A)* Shows centrifugal and gravity forces acting on the material in the elevator bucket to provide satisfactory discharge. Position of the inner lip of the discharge chute is for high and moderate speed elevators. *(B)* Shows centrifugal and gravity forces affecting pickup of material in the elevator boot. Optimum pickup occurs when the material is introduced at or above the foot wheel shaft

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958.

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When the mass of grain in the bucket is moving around the head pulley it is subjected to two forces (Fig. 1). One is the force of gravity acting vertically downward. The other is the centrifugal force acting radially from the center of the head pulley. The resultant of these forces causes the material to be discharged from the bucket into the discharge chute. For clean emptying of the buckets, the start of the flow from the bucket must be delayed until after the bucket has passed its uppermost position on the head wheel. This situation will exist when the gravity force and the centrifugal force are equal. When the bucket reaches the top position on the head wheel, the resultant of the two forces will be zero, and there will be no discharging force on the material. It will neither be thrown vertically from the bucket or fall out of the bucket and down the elevator legging (Fig. 1-A).

This equilibrium of forces is used to determine the relationship between pulley radius and speed to produce satisfactory operation.

$$W = WV^2/gR,\ V^2 = gR,\ V = \sqrt{gR}$$

$$V = 2\pi RN/60 = \sqrt{gR}$$

$$N = 60\sqrt{gR}/2\pi R,\ N = 54.19/\sqrt{R}\ (1)^*$$

W = Weight of material (lb)

V = Velocity of material (fps)

g = Acceleration of gravity (32.2 fps^2)

R = radius to the center of gravity of the material in the bucket (ft)

N = Speed of head pulley (rpm)

The graph in Fig. 2 shows the relationship between the head wheel speed and the radius of the path of the center of gravity of the material in the bucket about the center of the head wheel. To find the diameter of the head wheel, deduct from this radius the thickness of the belt and the distance from the belt to the center of gravity of the material in the bucket.

Since all particles of material in the bucket will not be the same distance from the center of the head shaft, the material will not discharge as a mass but will start first at the outer edge of the bucket. This would indicate that discharge would start too soon if the relationships for pulley diameter and pulley speed were based on the high-speed values from Fig. 2. However, in actual practice discharge is delayed until the resultant of the forces increases enough to overcome both internal friction in the material and the friction between the material and the sides of the bucket.

The trajectory of the material from the buckets is parabolic. It can be determined by use of the equations of motion. It has been found that for high-speed elevators, those with head-wheel diameters and speeds determined from the high-speed curve in Fig. 2, the inner lip of the discharge chute should be located as close to the descending buckets as possible and at an angle of 15 to 20 deg below the center of the head wheel (Fig. 1-A).

The loading of buckets at the foot of a centrifugal-discharge bucket elevator is also affected by the forces of gravity and centrifugal action. The resultant of the forces here prevent pickup of material until after the buckets have passed a point below the foot-wheel shaft. The resultant forces are shown in Fig. 1-B for various positions of the bucket when the foot wheel is the same diameter as the head wheel. Loading occurs as the buckets rise and cannot be completed until the bucket reaches a height level with the foot shaft. Material should be introduced on a high-speed elevator at the level of the foot shaft or above to obtain proper filling of the buckets. If foot wheels smaller in diameter than the head wheel are used the centrifugal force will be greater and loading must be done above the shaft center.

*Numbers in parentheses refer to the appended references.

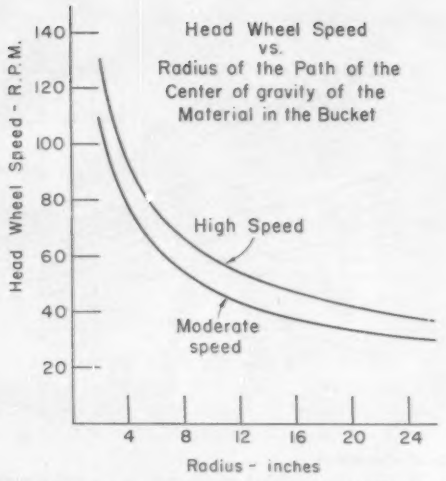

Fig. 2 The relationship between the head wheel speed and the radius of the path of the center of gravity of the material in the bucket for satisfactory discharge at high and moderate elevator speeds

The speeds and diameters of head wheels for high-speed centrifugal-discharge elevators are not satisfactory for handling light dusty materials such as ground feeds. The wheel speeds may be reduced by 82 percent as shown by the moderate speed curve in Fig. 2. This reduction in speed will reduce the dust problem and provide better pickup with less turbulence in the boot. Discharge will begin earlier because the gravity force will be greater than the centrifugal force. The resultant force will be vertically downward when the bucket reaches the top of the wheel. The material that is spilled will be carried out to the discharge chute by the fanning action produced by the buckets moving around the wheel. For this moderate speed elevator the inner lip of the discharge chute should be placed about 30 deg below the center of the head wheel (Fig. 1-A).

Elevator Capacity

The capacities of bucket elevators depend upon the capacity of the individual buckets, the bucket spacing, and speed of the belt or chain carrying the buckets. Bucket spacing is governed by the shape of the bucket and its resulting discharge characteristics. Buckets must be spaced to prevent discharge interference by the preceding bucket. Due to the direction of the discharging force, bucket spacing on high-speed elevators may be less than on moderate-speed, centrifugal-discharge elevators. In general, bucket spacing will be from two to three times the projected width of the buckets.

The capacity of a bucket is considered to be from 85 to 90 percent of the struck volume for high-speed elevators, if the feed is arranged to allow loading at or above the center of the foot shaft. If loading is below this point, the capacity may be reduced to 80 percent of the struck volume. On moderate speed elevators the bucket should be expected to fill 90 percent of its struck volume.

The following equation is used to determine elevator capacity (4):

$$\text{Elevator capacity (lb per min)} = \frac{\text{Bucket capacity (lb)} \times \text{Belt speed (fpm)}}{\text{Bucket spacing (ft)}}$$

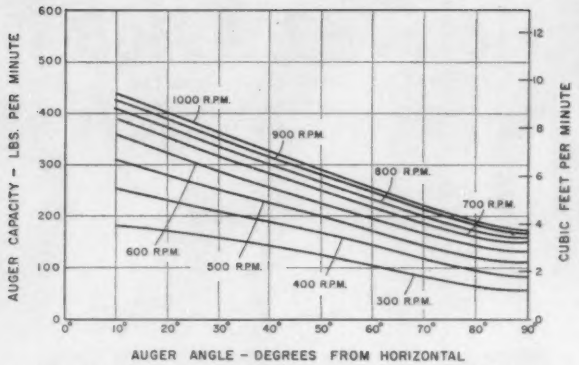

Fig. 3 The capacity vs angle of the 4-in. Cornell test auger conveying wheat weighing 56.5 lb per bu at auger speeds from 300 to 1000 rpm

Elevator Horsepower

The horsepower required to operate a bucket elevator is that required to lift the material, to scoop the material into the buckets, to discharge the material, to move a small amount of air, and to overcome friction in the bearings and other drive components. In general the bucket elevator has a high elevating efficiency. In practice it has been found that theoretical horsepower required to lift the material needs to be increased only 10 to 15 percent to obtain the actual power requirement. The following equation is used to obtain the theoretical horsepower (1):

$$\text{Horsepower} = \frac{\text{Elevator capacity (lb per min)} \times \text{Height(ft)}}{33{,}000 \text{ ft-lb per min}}$$

It is advisable in determining horsepower to use the struck volume of each bucket in determining the elevator capacity. This will eliminate power failures in instances where feed rate is high and the buckets are filling well above the center of the foot wheel.

The above are a few of the considerations in the design of a bucket elevator for handling free-flowing materials. One must also determine the best bucket shape for pickup and discharge of the material, the belt characteristics required, and the diameter of head pulley and belt tension to provide the necessary lift at the correct speed.

Auger Conveyors

The auger or screw conveyor, in which the auger is contained within a cylindrical tube, has been used extensively for both conveying and elevating free-flowing materials. Design information for low-speed horizontal operation is available, but very little information has been published concerning the operation of an auger in elevating materials.

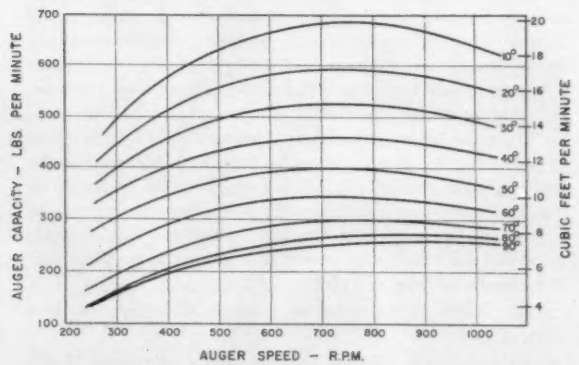

Fig. 4 The capacity vs speed of the 6-in. Cornell test auger conveying oats weighing 42 lb per bu at angles from 10 to 90 deg

Tests of auger conveyors have recently been made at Cornell(5) and at the University of California(6). Although different sizes of augers were used in the studies, there are some general conclusions that can be drawn from the work done at the two stations:

- Capacity increases as auger speed is increased to a certain point, after which it appears that a centrifugal action of the flights on the material at the intake prevents any increase in capacity.
- The speed at which maximum capacity is reached varies both with the material and the size of the auger. Maximum capacities occur between 700 and 900 rpm for 6-in. diameter augers and at speeds over 1000 rpm for 4-in. augers.
- The capacity in a vertical position is from one-third to two-fifths the capacity in the horizontal position.
- Auger horsepower requirement increases almost linearly with speed from 300 to 1000 rpm and varies with the type of material elevated.
- In the auger speed range from 300 to 1000 rpm maximum horsepower is required at elevating angles of 40 to 60 deg. Maximum elevating efficiency also occurs at these angles.
- Auger length has no effect on auger capacity nor on the horsepower required per foot of length.

The capacity of an auger conveyor depends upon a multitude of factors, including the physical properties of the material conveyed and the physical dimensions of the auger conveyor. To combine these factors into a workable formula has not as yet been possible. As a result of studies at Cornell, Rehkugler suggests a relationship that fits his data of auger capacity versus elevating angle with reasonable accuracy.

$$\text{Capacity} = A + B \cos(\theta + 90) \text{ Ref. 5}$$

A = Capacity in the horizontal position

B = Capacity difference between horizontal and vertical

θ = Elevating angle with the horizontal

The following table compares actual test results with computed values using the above formula. Variation is less than 6 percent.

COMPARISON OF COMPUTED AND ACTUAL AUGER CAPACITIES*

	Wheat – 56.5 lb per bu Wheat — 700 rpm		Oats – 42 lb per bu Oats — 600 rpm	
Elevating angle θ degrees	lb per min computed	lb per min actual	lb per min computed	lb per min actual
0	1140	1140	790	790
10	1019	1030	697	680
20	900	925	607	585
30	790	820	523	520
40	690	720	446	455
50	604	630	380	390
60	533	560	326	335
70	482	500	278	295
80	451	465	265	265
90	440	440	255	255

*Auger O.D. — 5⅛ in., auger pitch — 4⅞ in., auger shaft O.D. — 1 1/16 in., tube I.D. — 5⅛ in., and auger projection from tube at the intake end — 6 in.

The use of this formula to predict capacities at any angle between horizontal and vertical requires that capacity vs speed be first determined for the two boundary positions. This method still leaves much to be desired but would be of value in reducing auger test time.

Regan, in a graduate thesis study at the University of California, found that when conveying barley with a 6-in. auger, the volumetric efficiency in a speed range from 400 to 700 rpm could be computed from the following relationship:

Percent volumetric efficiency $= [(1419 - \text{rpm})(107 - \theta)/1425]$

θ = angle at elevation Ref. 6

If you know the volumetric efficiency at any angle and speed in the specified range the capacity could readily be computed. This would be a simple method of determining auger capacity if the volumetric efficiency did not vary with the auger dimensions or the characteristics of the material. However, the volumetric efficiency does vary. For example, the volumetric efficiency of the 6-in. Cornell test auger at 500 rpm operating horizontally was 63 percent for wheat and 56 percent for oats. Regan reported as much as 10 percent higher volumetric efficiencies for barley than was obtained by Rehkugler with wheat. These materials have similar physical characteristics but the auger dimensions were not the same. The California test auger used a full 6-in. screw diameter as compared to the 5⅛-in. screw diameter of the Cornell auger. The projection of the screw from the tube of the California auger was 16 in. and that of the Cornell auger was only 6 in. This screw projection from the tube at the auger intake probably is an important factor in obtaining greater volumetric efficiencies.

Both auger studies point to the need for experimental work to determine how material characteristics and conveyor dimension affect the performance of auger conveyors.

Samples of curves from the Cornell study are included to show some of the performance characteristics of the augers tested. The curves apply only to conveyors with the following dimensions:

Conveyor	Auger O.D.	Pitch	Shaft O.D.	Tube I.D.
6 in.	5⅛ in.	4⅞ in.	1 11/16 in.	5⅞ in.
4 in.	3⅜ in.	3⅜ in.	27/32 in.	4 in.

The auger projection from the tube at the intake end is 6 in. for both augers.

Auger Conveyor Horsepower

The horsepower required at the auger shaft increases almost linearly with increases of auger speed as shown by the uniform spacing of the rpm lines in Figs. 5 and 6. The maximum horsepower required occurs at angles of elevation between 40 and 60 deg. The angle at which maximum horsepower is required increases as the speed is increased. Both Rehkugler and Regan attempted to fit an equation to the horsepower data obtained but were unable to find a satisfactory relationship. Maximum horsepower per unit of length vs speed could be represented by a straight line. Such an equation would be necessary for each size of conveyor and for each type of material to be conveyed. However, these variations might be taken care of by varying factors in a general equation.

The type of drive from the gas engine or electric motor used on the conveyor has considerable effect on the total power required. Transmitting power from a motor at the base of a long conveyor to the head pulley by V-belts can cause power losses as high as 30 percent depending on the amount of belt slippage and the type of bearings used. The horsepowers shown on the graphs included here are those required at the auger shaft on the 6-in. conveyor and those required for the motor with a single short V-belt drive to the auger shaft on the 4-in. conveyor.

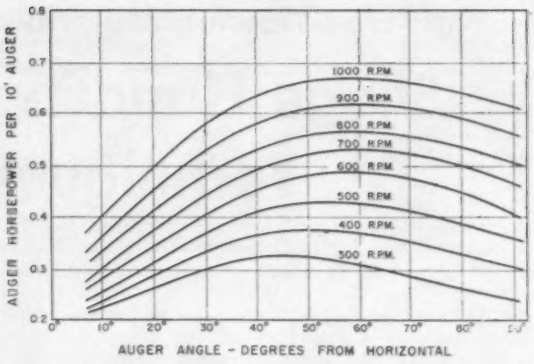

Fig. 5 Auger horsepower per 10 ft of auger (length measured from the center of intake opening to center of discharge opening) vs elevating angle for auger speeds from 300 to 1000 rpm, when conveying oats weighing 42 lb per bu with the 6-in. diameter Cornell test auger

Theoretical analyses by both Regan and Rehkugler resulted in very complex relationships to determine torque at the auger shaft. Their equations fell short of matching the horsepower obtained by test. At present it seems that auger horsepower and capacity must be determined by actual tests of the auger conveyor.

It must be recognized that to date there is not a satisfactory manner by which auger capacity and horsepower can be accurately predicted. Both Rehkugler and Regan indicate that much experimental work needs to be done to determine how the characteristics of a material and the auger dimensions affect the capacity and horsepower requirement of a conveyor.

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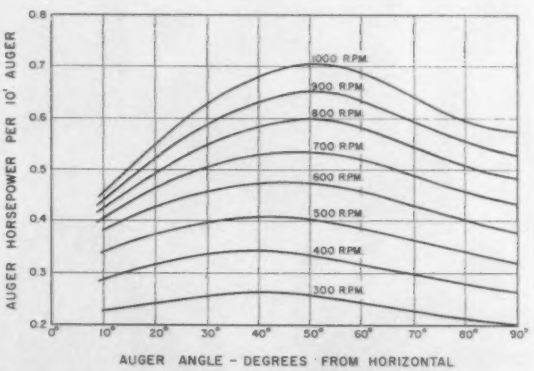

Fig. 6 Auger horsepower per 10 ft of auger (length measured from the center of the intake opening to the center of the discharge opening) vs elevating angle at auger speeds from 300 to 1000 rpm, when conveying wheat, weighing 56.5 lb per bu with the 4-in. diameter Cornell test auger

Non-Free-Flowing Materials:

Silage Handling Techniques

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Member ASAE

TAKING the "si(gh)" out of silage handling can be done with field choppers, self unloading wagons, silo unloaders, and automatic feeding equipment. But as researchers, development men, manufacturers, and salesmen, we still have to meet a tremendous challenge in developing and marketing new and better silage handling equipment. The farmer, like the corporation president, insists that any new equipment he buys for his farming business reduce labor. The new equipment must justify the original and maintenance costs by doing a better job and by providing a gain in net income. The farmer is not looking for, and will not buy, just a bigger and better wheel barrow.

Silage handling starts with cutting the crop. For higher quality grass silage, the material must be cut and conditioned before it is chopped. Length of cut is extremely important. A short-cut material *(short cut* is defined here as ½ in. or less in length) is best for many reasons. In automatic silage handling systems materials are made to flow by mechanical means. Long-cut materials will not flow easily.

Filling a cylindrical structure with a reasonably uniform short-cut forage gives these benefits: *(a)* more uniform density in the entire structure; *(b)* increased storage capacity; *(c)* more uniform unloading rate from mechanical unloaders; *(d)* reduced or "levelized" power requirements for the unloaders; and *(e)* improved compaction of stored material. Short-cut forages ferment faster because more stem ends are exposed. That fermentation is more effective with short-cut forage has been established by Dr. Rodney Briggs, University of Minnesota agronomy department. Feeding qualities are also superior in short-cut forage.

I would like to make a suggestion to those of you in the field chopper business. Have your operator's manuals, instruction books, sales leaflets, etc., recommend that forage be short-chopped. Show just how the user can adjust and operate the machine for a short cut. Most field choppers on the market today will give short-chopped material.

Moisture level may be misunderstood, especially in the way it affects total capacity of a storage unit. People promoting sealed storage systems recommend storing grass silage with 40 to 60 percent moisture and corn silage at the 50 percent level. Advocates of conventional upright storage systems feel that silage should be over the 65 percent moisture range. According to the Bureau of Dairy Industry Information Bulletin 149, a silo holds approximately the same amount of dry matter regardless of moisture content. The wilting and storing of drier materials overcome the disadvantages of storing high-moisture grass silage and field-cured hay.

Grass silage with 40 to 60 percent moisture content and corn silage with 50 percent moisture content overcome many disadvantages of silages in the higher moisture ranges through better retention of nutrients, elimination of barnyard mess from drainage, handling of less weight, no need for preservatives, more palatability, and a higher dry-matter intake. Field-cured hay has many disadvantages. Wet weather affects its quality. Leaf shattering is always great. Vitamin and nutrient loss is high. Labor is costly.

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958.

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Fig. 1 Strain lines on pin head *(below, left)* are revealed by etching action of acid. *(Right)*, Pitted surface and corrosion fatigue from acid attack cause bushing failure

Silage Acids

The attack of silage acids, causing corrosion of steel and the loss of strength of concrete, creates many problems. The attacking acid is acetic acid. The strength of the acids is illustrated by their pH values. Corn silage acid is 3.5 to 4.0 pH and grass silage is 5.0 to 5.5. Acetic acid reacts with the carbonates in the concrete. The carbonates and the lime salts are leached out, leaving the aggregate without much strength. To my knowledge, there is no permanent protective coating that can be recommended universally for preventing acid damage to concrete.

Silage acids aim their most damaging attack at steels used in unloaders and other machines of the "hardened steel" range. Of course, the acetic acids have a pickling effect on all mild steels. Acid damage to hardened steel appears mainly in the form of stress cracking or corrosion. Examples of this damage are shown in Fig. 1. Stress cracking does not appear in steels with less than a 42 Rockwell *C* rating. When hardened steels are specified in component parts of silage handling equipment, either for increased strength or longer wear, a good quality control program must be maintained to insure that the steel in its final manufactured form meets production specifications.

Metal for the inside of a silage storage structure can be protected from corrosion only by an acid-resistant glass or an inorganic coating.

The wetter the silage, the more severe the silage acid attack on concrete or steel. So, the lower the moisture level of the silage (down to 40 percent for grass silage), the better the silage — both from a feeding and nutrient standpoint and for reducing silage acid damage to steels and concrete.

Silage Distributors

Fig. 2 shows a picture of a top distributor we used for testing the effect of silage distribution as it is blown into the

structure. In preliminary studies comparing a structure with a top distributor to a structure without a distributor, we found that capacity was increased, power requirements of the unloader were more constant, and silage discharge unloader rate was more uniform. Also, segregation of the material was at a minimum. Dr. C. K. Otis, University of Minnesota, in his work on densities of silage in upright silos reveals, that with a silage distributor, the variation in density across the structure is reduced 10 to 12 percent.

Storage Structures

Storage facilities fall into two basic categories: the horizontal and the upright structure. The latter consists of the conventional silo and the glass-lined air-tight structure.

In both pit and stack storage the wall should be sloped at a specific angle. Certain economic considerations govern minimum as well as maximum capacity to determine the overall size of the bunker.

A bunker can be filled with a blower. The popular way, however, is to dump the silage, level it out, and then compact the material with a crawler-type or rubber-wheeled tractor. The term "efficient" cannot apply to this method.

The filling of both conventional upright silos and glass-lined structures follows the same present day methods. One difference between sealed storage and conventional units is in the annual use factor. Air-tight structures lend themselves to repeated fillings. I have seen one structure filled as many as five times per year.

Of the present ways to fill upright structures, blowers are the most popular. Flight-type elevators hold the second position. With the exception of one blower on the market today, blowers all follow a similar pattern. The material is removed from a wagon onto the blower carrier bed, then carried into the blower impeller and/or airstream. One make has a vacuum system to unload the wagon plus a blower to fill the structure combined in one unit.

Blowers have high horsepower requirements but their efficiency for converting power for the task of filling an upright structure is low. Considerable effort is being expended to develop more efficient means of filling. One different approach to a more efficient filling method is a belt-tube adaptation developed by Cornell University. The University of Illinois has a chain-type lift with attached carrying prongs. Purdue University has worked with a flinger-type unit using the basic components of a blower. Other work has been done with adaptations of bucket elevators. These experimental conveyors run on relatively low horsepower and their capacities could be high. Perhaps single-phase electric motors could be the power source.

We are now more efficient in the way we haul the chopped material to the structure and remove it from the wagon. Chopped material used to be pushed from the wagon with a silage fork. Then came the false endgate wagon. Next was the dump wagon. Now the self-unloading wagon has widespread acceptance. But we need a better way to get the chopped material from the field chopper into the carrying vehicle — especially with the shorter chopped materials. Too much chopped material is blown away by the wind before it has a chance to fall into the wagon. This loss of material can be costly.

In designing new equipment, remember that chopping, hauling, and structural loading equipment should all be kept in an operational balance. Don't let one piece of equipment be the definite limiting factor. Ideally the wagon unloading, filling, and distributing equipment would be of equal capacities, so the unit can operate unattended.

Unloading the Silage

Today's methods of silage unloading vary from the pitch fork to complete automation. In both pit and stack, front-end shovels and rotary-drum unloaders are most prevalent. There is some self feeding of the silage. Many conventional upright

(Continued on page 577)

Fig. 2 This photograph was taken during an experiment to measure distributor efficiency

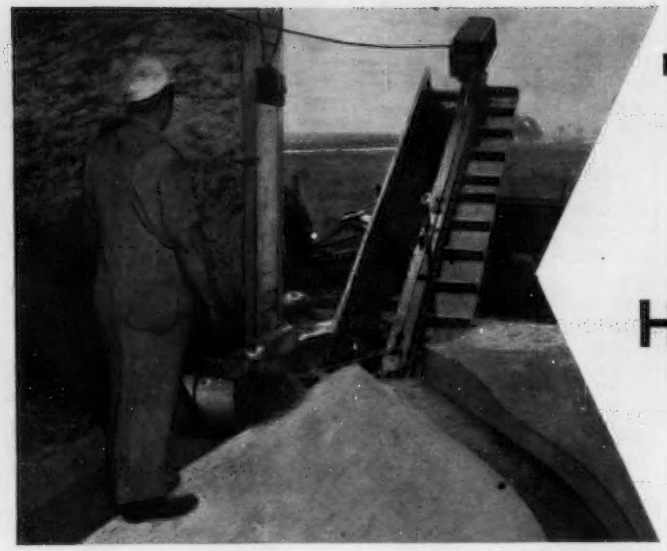

Fig. 1 Cable-pulled shovel-type gutter cleaner with elevator

Non-Free-Flowing Materials:

Handling Techniques for Hay and Manure

E. C. Schneider
Member ASAE

Daily farm chores could be lessened by mechanized handling of hay and manure. But how to overcome their non-free-flowing properties?

MECHANIZATION has greatly simplified materials handling on the farm — especially in field operations. While progress has also been made in developing machines for handling materials in the chore operations, their use still lags behind.

The objective of a better materials-handling program is, of course, greater efficiency. This may be accomplished by relocating storage areas in relation to point of usage and paths of travel, by adding mechanical equipment to replace man-hours and man energy, and by eliminating all need for handling the material. In the last 20 years the cost of farm labor has advanced about twice as fast as the cost of farm machinery, giving added impetus to the materials-handling program.

Handling Hay and Manure

Applying materials-handling principles to non-free-flowing materials, and specifically to hay and manure, is obviously more complicated because these materials are not free flowing. To apply these principles most efficiently we need to know more about the materials we are handling. Agricultural materials such as hay and manure are not as standard or uniform as many of the materials handled in industry, and for this reason present a greater problem. We need to determine the upper and lower limits of such factors as coefficients of friction, angles of repose, etc. for our materials. With this information as a foundation we can develop handling equipment with less trial and error. But to get this information and to develop new approaches to materials handling takes time and money.

Money for research is available from such sources as Federal, state, and private funds, including industry. Our progress could be faster if more funds were available. Increased funds from Federal and state sources are sought annually. We can encourage those industries with an interest in agriculture to review their contributions to, and support of, research in public institutions. Some industries may find it possible to give additional support.

Design Problems

In addition to having more research money, we need to hold a few "brainstorming" sessions to develop new approaches to materials handling. Proposals that seem far fetched in terms of the traditional approaches we usually rely on sometimes prove the most valuable.

Different types of agriculture in different sections of the country complicate the picture, too. The best way to handle hay and manure on dairy farms may differ in these various sections. Hay and manure handling may vary, too, on dairy or beef farms.

Another problem is farm size. Large and small farms often are both engaged in the same type of agriculture. We know there is a gradual trend toward consolidation and larger farms. The larger the farm, the more diverse and complete the mechanization of materials handling can generally be because of the larger economic base and the greater number of units handled by the equipment.

We must recognize, too, that certain practices will continue even though others may be more desirable. We may feel, for example, that loose housing on a dairy farm is better from a materials-handling standpoint. But we are still going to have stanchion housing. So there will be a continued demand for materials-handling equipment to use with stanchion housing.

Any materials-handling equipment design should reflect the fact that such equipment is often used a small percentage of the time. If the process permits continuous operation of the handling equipment and if the process can be made automatic (so that it does not require an operator in attendance), continuous or semicontinuous operation that moves smaller quantities per unit of time should be considered. This may permit greater economy because the equipment can be made lighter and require less power.

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958 and approved as Journal Series No. 78 of the Vermont Agricultural Experiment Station.

The author—E. C. SCHNEIDER—is chairman, agricultural engineering department, University of Vermont, Burlington.

Fig. 2 A coordinated system of bale handling from the baler to the storage structure

If the process requires an operator in attendance, the equipment should be designed to permit handling large units quickly to cut labor costs on the process.

Where possible, design the equipment to handle more than one material. For example, conveyors could handle both hay and silage for feeding—requiring only one conveyor instead of two.

It is essential to design all materials-handling equipment to fit into a coordinated and integrated system of handling all materials for a given operation. Such a system will result in fewer man-hours and simpler operation.

A coordinated system often demands that certain types and arrangement of buildings be used. It is not always possible to replace a perfectly sound set of buildings just to fit the materials-handling picture, even though it can be shown to be economically feasible. As a result, much of our materials handling approach is on a piece-meal basis and not necessarily aimed at having a coordinated system. Unfortunately, this may be necessary to meet the farmer's demands.

The coordinated system approach to materials handling may involve replacing existing field machinery that harvests and prepares the crop with machinery that puts out the material in a form especially adapted to the coordinated system.

Fig. 3 Dramatic proof of how the hay pellet reduces the volume of storage space needed

Manure Handling

Manure handling has two aspects: handling of manure dropped in the pasture; and handling the concentration dropped in the barn, barnyard, or feed lot. A recommended way of handling that dropped in the pasture is to break it up and scatter it with a tractor-pulled drag. Manure dropped in the barn and barnyard must be disposed of in some way — for health reasons if for no other. However, this manure is valuable and should be returned to the fields as fertilizer.

Occasionally poultry, sheep, and cow manure can be processed, packaged, and sold to home gardeners.

Manure handling should require as few man-hours as can be economically justified in terms of the cost of handling equipment.

For stanchion housing we have mechanical gutter cleaners of the reciprocating flight type, the chain and flight type, the belt type, and the cable-powered shovel type, as shown in Fig. 1. In addition we have the tractor-mounted, twin-gutter shovel type. All of these handle manure with less effort and in less time than if done by hand. We normally conserve the liquid manure by soaking it up with straw or shavings. Manure can be fluidized and pumped. However, expensive equipment and storage are required and the ammonia is easily lost.

From an agronomic standpoint, manure should not be

Fig. 4 *(Left)* Heated air wagon hay drying

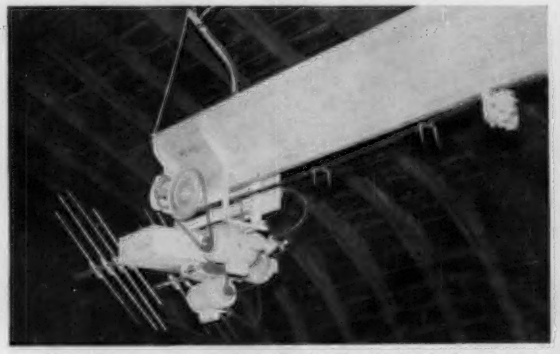

Fig. 5 Conveyor fed distributor for distributing hay in the mow

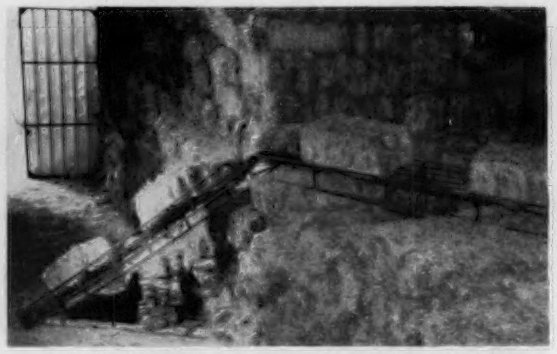

Fig. 6 Portable sectional conveyors or elevator for moving bales

. . . Hay and Manure

spread when the ground is frozen. Much of the valuable fertilizer leaches out and runs off as surface water. In snowy and cold climates the manure should be stockpiled, preferably under cover, until the frost is out of the ground. For stanchion housing this may require a storage structure. An inflatable plastic building might handle this economically. For loose housing the loafing barn is its own storage structure. However, the manure from the feeding area must be handled separately and similarly to that from the stanchion barn.

For handling manure from the loafing barn, feeding area, and storage structures we have tractor-mounted scrapers, loaders, and, of course, manure spreaders. The handling of manure is well mechanized. However, new ideas should be considered and the equipment we now have improved.

Hay Handling

We have made progress over the years in our methods of handling hay from the field to the animal. More progress can be made, but we must consider certain limiting agronomic, economic, and animal husbandry factors. In applying materials-handling principles to hay, we begin with the standing crop, since that is where our handling starts.

Even though we no longer do it by hand, we still go over the field too often and handle the hay too much—once to cut it, once to crush or crimp it, once to rake it, once to bale it, and once to pick up the bales. One or more men are involved in each operation. The picture is just as bad with chopped hay, worse with long hay, which, fortunately, is on the way out. One machinery manufacturer has developed a bale-handling system that reduces the number of passes and the number of men as shown in Fig. 2.

If we could develop a machine to process the hay in one pass over the field to a point where it is ready to be moved to storage, we would reduce labor costs, weather hazard, and possibly soil compaction. Such a machine would admittedly be costly and require a high energy input.

One potential power source is atomic energy. Heat is needed to dry hay—heat is a product of an atomic reactor. Water is needed for cooling the reactor—water is a waste product in drying hay. The water driven off from the hay in drying could be condensed by a refrigeration unit powered by the reactor. Pelleting requires large amounts of power such as could be available from the reactor. Such an idea might come out of a "brainstorming" session. While we're not ready for it yet, this could be kept in mind for further investigation.

The form hay is in when ready for storage is either long, chopped or baled, none of which is easy to handle. Pellets are currently being investigated. They take up less space (Fig. 3). They could preserve more of the plant as grown. They may lend to free flow and thus be easier to handle than long, chopped, or baled hay.

Other forms hay might take could be small self-tied bales and biscuits, both of which might adapt to free flow.

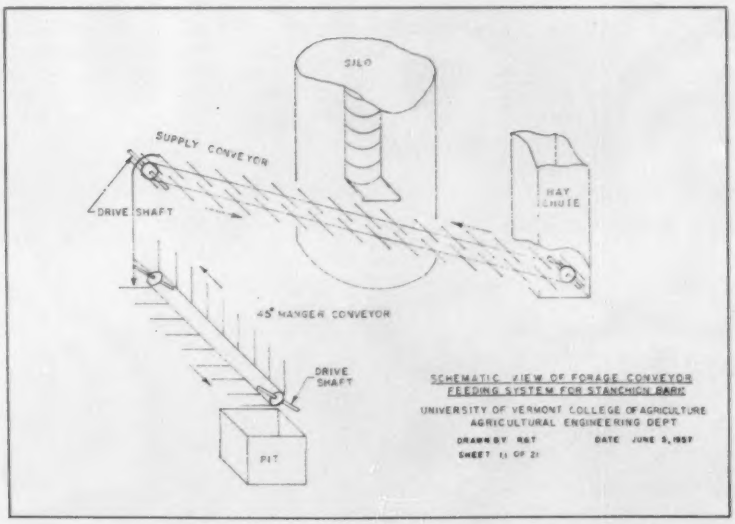

Fig. 7 *(Right)* Schematic view of forage conveyor feeding system for a stanchion barn

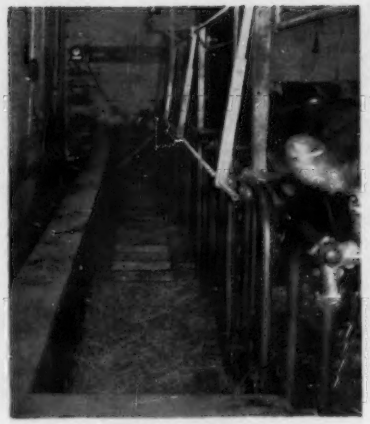

Fig. 8 *(Left)* Manger feeding conveyor looking toward discharge end. Electric cow trainer chains are down • Fig. 9 *(Right)* When all feed has been distributed, trainer chains swing up and out of the way

Probably the best application of materials-handling principles to the handling of hay is to make the hay a free-flowing material. Certain structures, such as the self-feeding tower silo, might be altered to handle chopped hay.

Handling hay in its present forms also involves drying it with forced heated or unheated air. This can be done in the storage structure or, if heated air is used, in drying wagons as shown in Fig. 4.

Much equipment has been and is being developed to handle hay in its present forms. Hay distributors, as shown in Fig. 5, spread the hay evenly and mechanically in the mow. Stackers, stack movers, blowers, conveyors, and elevators, such as the one shown in Fig. 6, all reduce the man-hours required for handling hay.

When feeding hay we can use the self-feeding principle—the cardinal principle of materials handling—"Don't handle it if you don't have to." Some current agricultural practices, such as stanchion housing, require that we do handle the hay in moving it from storage to the cow. To mechanize this process and reduce the labor involved, the agricultural engineering department at the University of Vermont has developed a conveyor feeding system for feeding hay and silage to dairy cows in stanchions. This is shown schematically in Fig. 7. The system consists of a supply conveyor and a manger conveyor.

The supply conveyor originates under a hay pitch hole from the overhead mow. It runs past the silo and discharges onto the conveyor in the manger. Controlled atomatically, an unloader in the silo delivers a weighed amount of silage for each cow. The operator pitches hay down until a buzzer signals him that the required amount has been delivered. The remainder of the operation is automatic. When the feed reaches the last cow, the system stops until the next feeding cycle.

An electric fence trainer prevents the cows from eating the feed as it goes past them (Fig. 8), after the conveyors stop. The trainer then swings out of the way, as shown in Fig. 9, so that the cows can eat.

The system offers economies in time, travel, and energy. It is adaptable for use with loose housing of dairy cows and other livestock. In tests with eight cows in stanchions, as much as 80.2 percent of time and 88.2 percent of travel were saved by conveyor feeding as compared with hand feeding.

Work is currently being done on metering the hay in weighed amounts to each cow. This is an attempt to develop an integrated system reducing the labor to handle hay and silage, in their presently used forms, in stanchion housing.

. . . Milk Handling

(Continued from page 545)

be willing to buy leisure time that from a true economic standpoint could not be justified.

The capital expended on materials-handling facilities on dairy farms vary widely. Some non-operating owners, with other sources of income, have spent fortunes in setting up pipe-line parlor milking systems. Other practical operators have provided very efficient set ups at a reasonable cost. In all probability there has been many instances of dairy farmers buying milk-handling equipment that could not be justified from a true economic standpoint.

In the final long term analysis improved milk-handling equipment must stand the test of whether the additional investment will increase the net return in an amount compatible with the increased investment.

Summary

Progress in improved materials handling of milk on the farm was relatively slow prior to World War II. Since that time substantial progress has been made, with some developments of a revolutionary nature.

The engineering tools of work simplification, time and motion studies, and work place layout analysis offer an effective means toward the improvement of materials-handling methods and equipment used in milking operations, as well as a means of measuring the relative efficiency of alternate methods.

Economical materials-handling equipment is available today that can greatly improve the declining but still important can-handling system.

The development of the bulk-tank system together with the milking parlor and pipe-line milking with automatic cleaned-in-place equipment, provide an approach to push button materials handling of milk on the farm.

The economics of materials-handling methods and equipment in the milking operation should consider the farm as a total economic unit. The basis of the economic value of alternate methods and equipment should be (1) improved quality, (2) reduced production costs, and (3) reduced physical effort, to the extent that true dollar values can be placed on each of these factors, then the net increased return can be weighted against the added capital required. The many variables that exist on different dairy farms suggests an economic analysis of alternate methods based on each individual farm.

How Automatic Equipment Solves Handling Problems of

Non-Free-Flowing Materials

H. B. Puckett
Member ASAE

AUTOMATIC materials handling signifies that materials are available through mechanical means at a specified location, in a specific quantity at a desired time. This may be either in a continuous flow or a batch system. Either system must be capable of supplying the demand for materials at the time and in the quantities desired. Reliability is necessary in any materials-handling equipment. Automatic materials-handling equipment that lacks reliability fails to accomplish the task for which it was designed.

Small automatic electric materials-handling equipment that can improve labor efficiency and reduce drudgery on the livestock farm has been the objective of cooperative farm electrification research at the University of Illinois. Smaller electric equipment, capable of automatic operation for an extended period of time requires a lower capital investment and a more favorable power demand, which will result in more satisfactory distribution of the electrical load for the benefit of the farmer and the power supplier.

Electric equipment is most economical to own and operate when it can be profitably used in continuous operation. Continuous operation makes the maximum use of completely automatic controls.

Materials that are generally not free-flowing or which compact in storage require careful selection of the conveying and metering facilities. Materials such as ear corn, ground feed, oil meals, and fertilizers tend to compact in storage and are difficult to remove in small amounts.

A successful ear-corn crib drag† developed at the University of Illinois has been applied in many automatic ear-corn grinding installations. This crib drag operates in a relatively small hopper (approximately 1,000 bu). The hopper could be larger, but an increased size would require larger components and a larger power unit for the same delivery rate. The rapid growth of the picker-sheller for the harvesting of shelled corn has decreased the demand for this type of metering and removal unit, and few have been installed in recent years.

Ground feeds, oil meals, and fertilizers are being used in increasing volumes. Price discounts for bulk purchase of the material are an economic advantage for the user. However, the difficulty of removing this material from storage can, in some instances, erase any economic advantage to bulk purchase. These ingredients, when stored in large quantities and held in a static condition for several weeks, will tend to cake and complicate removal. Hopper-bottom bin storage has not been the complete answer to the removal of such materials. Not only does hopper-bottom storage cost more per cubic foot than common flat-bottom storage, but a flow of material from storage is not always assured. Some unloading device that can assure positive flow of material from storage is needed.

Auger Bin Unloader

The automatic auger-type flat-bottom bin unloader (1)*, Fig. 1, was not developed to meet the need for a low-capacity unloader for general storage bins that may be moved only once or twice a year. It is intended for active storage areas from which material would be removed frequently, as in an automatic, continuous-flow feeding system.

The unloader consists of two augers. A discharge auger removes material from a small hopper located in the center of the storage. A second auger sweeps the storage floor, bringing materials from the sides of the storage into the center hopper. Each auger is driven by a small electric motor. Separate motor drives are used so that the sweep auger could be controlled electrically by the amount of material in the discharge hopper.

Continuous operation of the sweep auger is undesirable. If the discharge end of the sweep auger is covered, a large amount of power would be required and would not contribute to the unloading or removal of the material from storage. If the sweep auger operates only when the discharge end of the auger is free to discharge into the center hopper, less power is required and delivery rate of the unloader is not affected.

Manual control of the sweep auger is not desirable. If the material bridges over the discharge hopper and the sweep auger does not start automatically when the discharge hopper is empty, flow of material from the bin would be interrupted until such time as the sweep auger could be manually started. Operating the sweep auger for only a very short time breaks such bridges as may form over the discharge hopper in normal operation.

This flat-bottom bin unloader is basically very simple (Fig. 2). The torque in the vertical drive shaft of the sweep auger propels the sweep auger over the bin floor. The torque in the vertical drive shaft is raised by slowing its speed with an input speed reducer driven by the motor, and then increas-

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958. Work reported is a result of cooperative research between the Farm Electrification Research Laboratory of AERD, ARS, U.S. Department of Agriculture; the agricultural engineering department of the University of Illinois, and the Illinois Farm Electrification Council.

The author — H. B. PUCKETT — is agricultural engineer, Farm Electrification Research Laboratory, AERD, ARS, U.S. Department of Agriculture, University of Illinois, Urbana.

†Illinois Plan No. 513, "Crib Drag and Hopper Bottom for Automatic Ear Corn Grinding."

*Numbers in parentheses refer to the appended references.

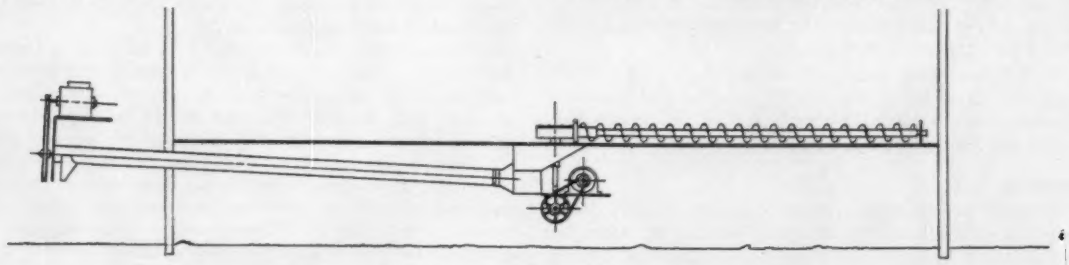

Fig. 1 Cross section of unloader in bin

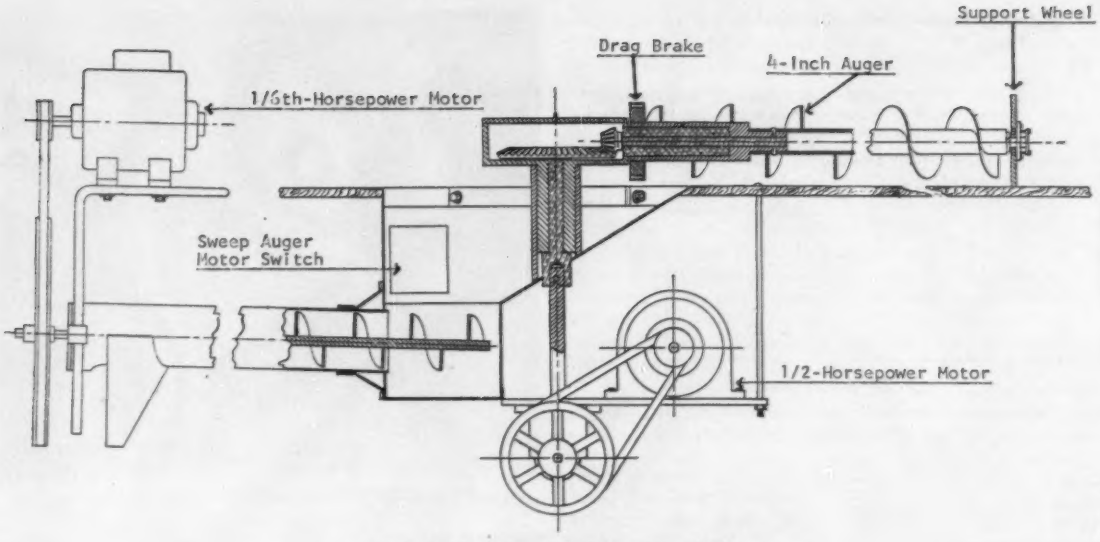

Fig. 2 Sectional view of flat-bottom bin unloader

ing the output speed of the gear box driving the sweep auger. The sweep auger is driven at approximately 150-200 rpm. By increasing the ratio between the two gears in the final drive, it is possible to use a low vertical-drive-shaft speed with high torque to power the sweep auger. This high torque in the vertical drive shaft is the force utilized to propel the sweep auger into the stored material. A drag brake is added to the sweep auger to increase the torque in the vertical drive shaft if it is needed. Regulation of this drag brake loads the auger properly in a particular material.

The sweep auger is rotated counter to the direction it would travel if it were in contact with the floor. This causes the auger to convey the material on the leading side of the auger. It also requires that the auger be suspended clear of the floor. For a long auger, a support wheel at the outer end is required. This wheel is not powered. The nearer to the floor the sweep auger is mounted, the cleaner will be the bin at the completion of operation. The nearness of the auger to the floor is limited by the evenness of the bin floor. The sweep auger must be able to clear all high spots in its arc of revolution. The auger conveys the material on the leading side and no shield is required. This reduces the drag or turning force required to propel the auger over the bin floor.

The flat-bottom bin unloader has been used successfully with soybean meal, oats, and shelled corn. It can be adapted for use with fertilizers and high-moisture shelled corn.

The power requirement of the auger unloader is low. Efficiency of the auger unloader is not high, but because its delivery rate is low, it can be operated by small motors. The low rate of delivery of the unloader will adequately meet the needs of most automatic materials handling systems.

Control Systems

Two control systems have been developed for this flat-bottom bin unloader. A current-sensitive relay with a power-controlling relay was first developed. The current-sensitive relay, Fig. 3, was installed in the circuit of the discharge-auger

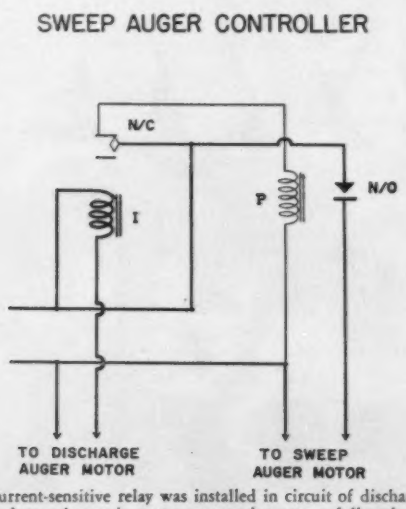

Fig. 3 Current-sensitive relay was installed in circuit of discharge-auger motor to detect change in motor current between a full and an empty discharge auger

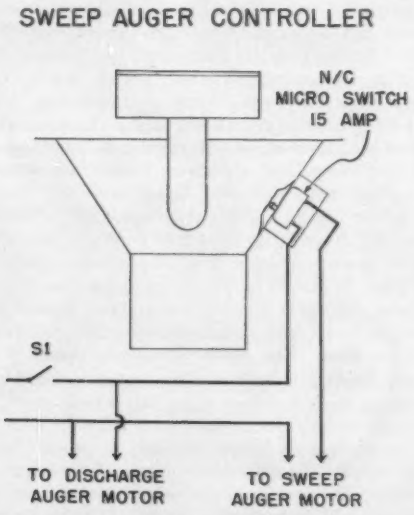

Fig. 4 Pressure switch requires only one electric device to control the sweep auger

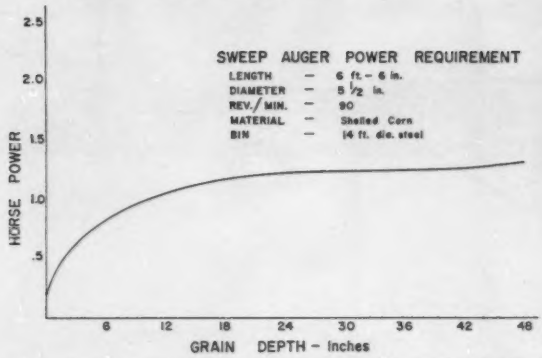

Fig. 5 Sweep-auger power requirement is affected more by length of sweep auger than by rate of discharge

motor to detect the change in motor current between a full and an empty discharge auger. The current relay was sensitive to a change of less than 0.3 amp. When the current of the discharge-auger motor decreased, the current relay closed, which energized the power relay controlling the sweep-auger motor. The sweep auger brought more material from the sides of the bin to the center discharge hopper. This operation was completely automatic—"off-on" control continued as long as was necessary to keep the discharge hopper filled.

A disadvantage of this controller was that a motor with a near-unity power factor was required for the discharge auger over a wide range of load, causing maximum change in motor current with load. A capacitor-start induction run motor was used. A repulsion-induction motor was not satisfactory because the current change due to loading of the auger was not sufficient to reliably operate the current relay. The current relay had to be adjusted for different types of material stored in the bin, and its adjustment was critical.

A pressure-sensitive switch was one of the first control devices considered to regulate the sweep auger. At first it was thought that this switch would not be responsive to the small changes in grain depth required to control the operation of the sweep-auger motor. Its simplicity caused its reconsideration as a control device for this purpose. In operation, the sensitivity of the pressure switch mounted in the discharge-auger hopper has proved satisfactory and eliminates disadvantages that were inherent in the current-relay controller. The pressure switch is simple (Fig. 4), requiring only one electric device to control the sweep auger. It is not affected by motor type or type of material being handled by the unloader. The pressure switch consists of a small microswitch, capable of handling up to a 1-hp electric motor, and a pressure plate. It is necessary to install a power relay to control larger motors.

The power demand of the discharge auger is very small, requiring only about ¼ hp for a 2 to 3-ton per hour discharge rate. The power requirement of the sweep-auger motor is affected more by length of the sweep auger than by the rate of discharge—¾ hp is sufficient for a 5½-in outside diameter sweep auger 6½ ft long and discharging 2 to 3 tons of feed material per hour. The power demand is shown in Fig. 5.

Seventy-five inch-pounds of torque were required to rotate a 6-in outside diameter sweep auger 3½ ft long, and 275 in-lb were required to rotate a 5½-in outside diameter auger 6½ ft long. The amount of torque required to propel the sweep auger varies approximately as the square of the length.

Increasing the capacity of the unloader would not be difficult. Its principles of operation would remain the same—the components would be increased in size.

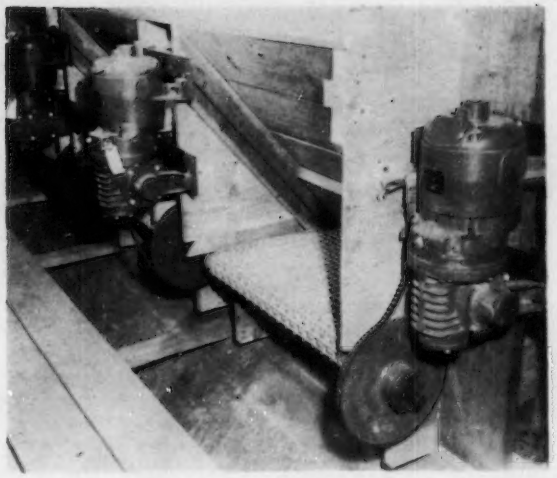

Fig. 6 A metal-belt meter installed as the floor of a bin

Metering Devices

Meters suitable for the handling of non-free-flowing materials require some special consideration—either in their type or method of application. The metal-belt meter, Fig. 6, which covers the entire floor of a storage bin, is suitable for non-free-flowing material. Less expensive meters may be used for metering non-free-flowing material if the material can be mechanically removed from storage and kept moving without compacting. Under this condition, several types of meters can be applied (2). Two of the most satisfactory are the auger meter, Fig. 7, and the vibrator meter (3), Fig. 8. In either of these the material must be sufficiently stirred to maintain free flow, for each depends on gravity feed from a small holding bin into the metering section. The flat-bottom bin unloader can be used to supply a small hopper from which material would be fed by gravity into either of these two meters. The hopper must have low capacity so that the material will move fast enough to prevent compaction. A feed-pressure switch in the hopper controls the bin unloader and keeps the hopper full.

The vibrator meter consists of a box with a trough on one side that extends out several inches and an electric solenoid

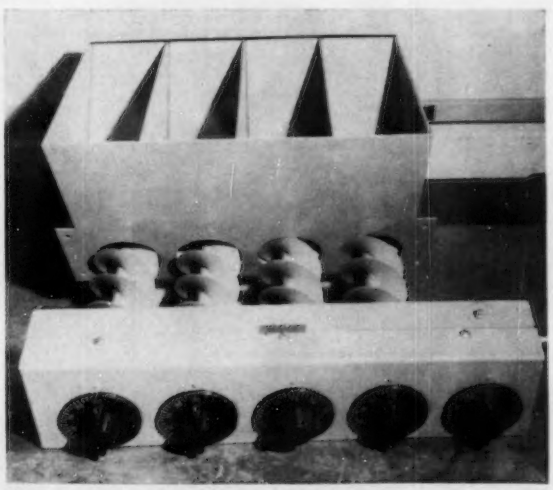

Fig. 7 A commercial auger meter. The dials control the relative speeds of the augers

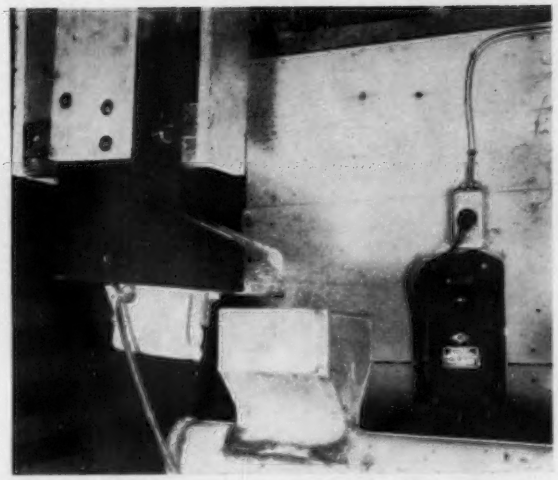

Fig. 8 A vibrator meter, installed under a bin, meters oats into a conveying auger

vibrator attached to the bottom of the trough. The sides of the meter are made of heavier gage material than the bottom. This confines most of the vibration to the bottom of the meter assembly and reduces the vibration in the sides of the box and the mounting. The amount of material on the trough is controlled by a gate. This is one method of controlling the capacity of the meter. The forward movement of the material is controlled by the amplitude of vibration and is regulated by either of two methods: by regulating the air gap of the solenoid, or by controlling the voltage impressed on the coil. The voltage to the coil of the small vibrator used in the development of this meter is controlled by a series rheostat that varies the impedance of the circuit.

The usual method of regulating capacity is to set the gate for the approximate rate desired and then regulate the coil voltage with the series rheostat for close adjustment of flow. A second method that sometimes may be desirable is as follows: Close the air gap on the vibrator armature so that small change in amplitude is realized with coil voltages in excess of 95 v; then regulate the rate of delivery by adjusting the gate controlling the amount of material on the meter trough. Such regulation is desired when the output of the meter must remain constant with minor fluctuations of line voltage. This would be the case if the meter is used in a blender along with another meter which was not sensitive to voltage fluctuations.

The trough of the vibrator meter was sloped 5 deg below the horizontal. This imparts a forward movement to the material as it vibrates and increases the capacity of the meter.

The vibrator meter has a throat large enough to pass trash and fair-sized lumps of material that might completely block other meters. Trashy or lumpy material will affect the rate of delivery while it is passing through the meter.

The flat-bottom bin unloader and suitable volumetric meters will satisfactorily meet the requirements of most materials handling in an automatic continuous-flow system.

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. . . Non-Free-Flowing Materials

(Continued from page 542)

This flow creates a flow pressure that is reduced and more easily dissipated when flow occurs over a contracting surface. When filling by flow occurs outward over an expanding surface, the flow pressure expresses itself on the bin wall and probably helps create an uneven pressure distribution along the vertical wall of the bin. A rotary-reaction-type distributor will apply the material to the periphery when used with a blower (Fig. 6).

Several investigators have studied pressures occurring within the stored material (2, 6, 7). Non-uniformity in pressure distribution is great. Filling methods need to be improved to reduce the differences.

The second principle of materials handling is to apply the material uniformly to as large an area as possible.

When granular materials will not flow by gravity, they can be assisted. A common method is to introduce compressed air through the bottom of the bin. This fluidizes the material and enables it to flow. For infrequent stoppages an air lance can be used.

The third principle is to change the characteristics of the environment surrounding the material so that it will flow.

Finally, if flow cannot be obtained by any of the methods discussed, a mechanical device can be used to remove the material from the storage. This is the fourth principle.

In summary, encourage granular materials to flow the way they flow easiest, over an expanding surface. Exploit weak properties in fibrous materials to make them break up and flow. When filling a storage, distribute the material uniformly over the largest area possible, and if part of the bin fills by flow, make it flow to the center. Fluidize when the characteristics of the material need to be changed. For the most difficult cases, use mechanical means to remove the material from the storage.

This subject needs much attention. It is hoped that this discussion will encourage greater effort in accumulating accurate information about the properties of materials commonly handled in agriculture and industry.

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(Continued on page 571)

Unit Handling of Fruits and Vegetables

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With soaring labor costs, researchers are developing methods of mechanizing movement of fruit and vegetables from the picker's bucket to the processing plant

LAST year approximately two billion fruit and vegetable containers were picked up, moved and set down five to fifteen times during their trip from farm to processing plant or market. These containers each had a capacity of 25 to 100 lb — type and size vary for different crops. These containers facilitate handling, protect the products, facilitate preparation of the product, provide a means of owner identification, and increase the flexibility of the operation.

Most containers now in use were designed for manual handling. Most agricultural workers can pick up and move weights up to 100 lb.

Design Criteria

Many fruits and vegetables are highly perishable and bruise easily. Containers for these items must protect against injury due to impact and pressures. In some cases they must also allow ventilation for cooling, etc.

Many commodities must be stored and conditioned. Packages must allow for heat transfer, air circulation, ripening, de-greening, and other processes. A good container should also allow for flexibility of movement.

In many areas, growers bring their products to one central point for packing, storing, grading, processing, or other preparation. Here each grower's lot must be identified by marking each container.

Although costs and maintenance of product quality are the major factors involved in choosing containers and a handling system, the above features should be kept in mind, too.

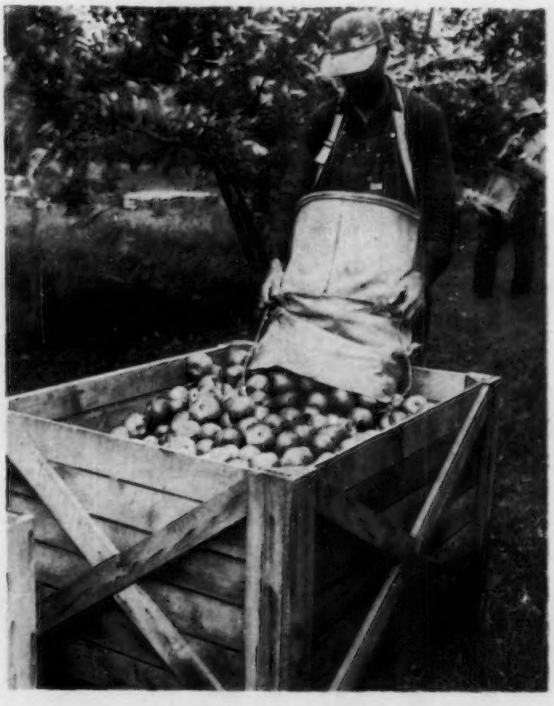
Piece-by-Piece Handling of Small Units

Until about 1950 millions of small unit containers were all handled individually. This piece-by-piece method was costly, time-consuming, and required many workers. Although this system usually involves the smallest investment in equipment, it requires the largest amount of labor. Fig. 1 shows the receiving area at a large processing company before it converted to bulk box handling. Since the conversion the company has cut its help here from 25 workers to 2.

Usually, wood field crates were used in handling fruit. These containers cost between 50¢ and $1 each. They are easily broken. Each year many were misplaced, damaged or lost — average container life was about 5 years, so replacement costs were high. A crate of apples or a lug of cherries was often picked up and set down 10 to 15 times during the harvesting and packing operation. Not only has the piece-by-piece method of handling become costly and difficult, but it is

Fig. 1 10,000 field crates of apples are stacked in this receiving area. Handling these containers one at a time is time-consuming, hard work

Fig. 2 *(Above)* A pallet load of cherries being transferred from the orchard trailer to a truck for movement to the processing plant. Handling cherry lugs on pallets saves approximately 2½c per lug in labor costs • Fig. 3 *(Below)* When bulk boxes are filled in the orchard, the picker empties his picking bucket into the bulk box. This system saves about 13c per bushel of apples handled



Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958.

The author — JORDAN H. LEVIN — is head, fruit and vegetable harvesting and processing section, AERD, ARS, U.S. Department of Agriculture.

Fig. 4 A tractor equipped with lift attachments on both the front and rear ends moves two 20-bu boxes out of the orchard. One man with such equipment can move 1500 bu a day

Fig. 5 *(Above)* Cherries are poured from the picker's pail onto the sorting table, then into a tank truck • Fig. 6 *(Below)* The driver unloads the cherries by opening the valve and fluming them out

becoming increasingly hard to find the necessary labor to perform this menial task.

Since World War II conveyors have come into wide-spread use in conjunction with individual unit handling. Roller or skate conveyors are used for horizontal movement. Power conveyors are used for in-storage stacking or truck loading. Most fruit growers have six to ten 20-ft lengths of conveyor, the total cost of which is from $300 to $400. Many producers also have a power-conveyor, which costs from $600 to $800.

Unit-Load Handling

The unit-load principle of handling a number of containers at one time came into wide-spread use in industry during World War II. In agriculture, until about 1949, the unit-load principle was used only in packing houses, storages, and the farm yard. Dollies and hand trucks, and, to a limited extent, skids were used.

A *dolly* is usually a rectangular platform supported by wheels or casters. Several containers are placed on a dolly by hand and the unit-load pushed to its destination. Dollies require a smooth surface.

Hand trucks vary in design. The *stevedore* has an L-shaped frame mounted on wheels and a pair of handles separated by stretchers. The load is carried by the lower end of the unit on a metal blade. Other types are the *clamp truck* and *four-wheel platform truck.*

A *skid* is a platform elevated from the floor by legs, casters, or other special attachments. Because of the clearance from the floor it can be lifted and moved by hand or by power-lift equipment. Loaded skids cannot be stacked.

Fork Lift Trucks. Fork lift trucks are machines designed to lift, move, and stack materials. They lift heavy loads easily, move them rapidly, stack them high, and set them down gently. The operation of fork lift equipment is simple and relatively inexpensive. In 1950 a USDA - Michigan State University study showed that in handling fruit, fork lift trucks and pallets save time, money, and manpower (Fig. 2) (3)*.

Pallets resemble skids, but can be placed on top of other loaded pallets in high stacking. They may be made of wood, metal or other materials, but the wood pallet is almost universally used for agricultural products. Pallets usually have an upper and lower deck spaced and held together by wooden stringers. They are lifted and moved by the forks of the lift equipment, which are inserted in the opening between the two decks. A number of containers can be placed on a pallet and handled as a unit load. This system of handling is now in wide-spread use in many areas of the United States.

Tractor Lifts. For use in the field or orchard, tractor fork lift attachments are now available for all standard-make tractors (5-6). Forks can be attached to tractors with 3-point hydraulic hitches. The necessary labor and materials cost approximately $50. Although an attachment of this sort will lift unit loads only about 18 in., it can move filled boxes from the orchard or field to the dock, packing house, or storage.

Forks can be bolted to tractor-mounted hay loaders or buck rakes for about $50. If this equipment is to be used in handling pallets, a third cylinder (costing an additional $50)

*Numbers in parentheses refer to the appended references.

enables the operator to keep the forks level while they are raised or lowered. Although buck rakes and hay loaders are not designed primarily for handling unit loads, this equipment makes it possible to raise the load 10 to 12 ft and is satisfactory if operated with care.

Lift attachments to lift and tilt the forks are available for both the front and rear ends of practically every standard-make tractor (Fig. 4). These operate in the same way as those on industrial lift trucks. They can be used for lifting, moving, and high stacking of unit loads. They cost $450 to $1,000, depending on capacity and height to which the forks can be raised.

Tractors can be converted to relatively permanent fork lift units. The lift mast is attached to the rear of the tractor. The gears, steering mechanism, and driver's seat are all reversed. Driver faces the load and all normal travel is in that direction.

Some growers make their own orchard lift units. This is usually done by shortening an old truck chassis, reversing the axle and steering mechanism, and adding a lift mast. When well built, such a unit can be operated successfully in the orchard or field. The cost of necessary material is about $1,000.

Industrial fork lift units having capacities of 1,000 lb and up are available for use at the dock, storage, or packing house. A lift unit with a capacity of 2,000 lb is suitable for most agricultural handling operations.

Industrial lifts may have either pneumatic or solid tires. If the machines are to be operated exclusively on warehouse floors or paved areas, solid tires are usually best. Less maintenance is needed and they give greater stability for high stacking. If, however, the unit is to be used on gravel or other irregular surfaces, pneumatic tires, with their larger diameter, wider tread, and greater resilience and traction, are better.

Lifts are powered by either electric motors or gasoline engines. Gasoline engines are probably the most practical for handling fruits and vegetables. The initial cost is lower, battery charging equipment is not necessary, and they can be operated almost continuously. However, if the lift is to be used in an enclosed warehouse or storage, the problem of exhaust fumes must be considered. Although mufflers designed to eliminate noxious fumes are on the market, an electric motor may prove most satisfactory when exhaust fumes are a problem. Industrial fork lift trucks suitable for agricultural commodity handling cost from $3,000 to $5,000 or more, depending on the capacity and type.

In handling apples, the pallets are usually placed on the bed of the orchard trailer. When the trailer arrives at the picking area, the filled crates are placed on the pallets by hand. Or the pallets may be placed on the ground in the orchard, loaded by the picker, and placed on the orchard trailer by a tractor fork lift. From this point on, all handling, whether it be transfer to road trucks, into and out of storage, or to the packing line, is done by lift equipment.

In handling fruit, fork lift equipment saves time, labor, and money. It also helps maintain quality and reduces congestion, spillage, overtime, and container breakage. The economies effected in on-the-farm handling of apples amount to about 5.6¢ per crate. Any grower who handles 10,000 bushels yearly can afford this equipment.

Large Unit Handling — Bulk Boxes

Although unit load handling has many advantages, many small, expensive containers are still needed. So many growers with lift equipment replace several small containers with one large one — a bulk box.

The bulk box, sometimes called a pallet box or bin, is essentially a combination pallet and box holding 15 to 40 bu. The pallet forms the floor of the box. The sides and bottom are usually slatted. When full, bulk boxes weigh 1,000 to 1,800 lb — so can only be handled with lift equipment. They handle and stack easier than palletized crates.

A USDA-Michigan State University study shows that handling apples in bulk boxes saves 13½¢ per bu (2) as compared to a palletized operation.

Such crops as onions, potatoes, pumpkins, beets and some other vegetables, apples, processing pears and peaches, and oranges can be handled in bulk boxes without lowering the quality of the product. In fact, one of the main advantages of bulk handling of apples is less bruising. This is probably because there is about two-thirds less surface area per bushel in a bulk box than in a field crate and because the fruit is handled more gently in a bulk box.

In handling apples, the bulk boxes are usually distributed in the orchard. When a picker's bucket is full he walks to the nearest box, leans against its side, and allows the fruit to flow into the larger container (Fig. 3). The filled boxes are moved to a storage, packing house, or nearby orchard dock for loading onto trucks (Fig. 4).

About 10 to 12 percent more fruit can be stored in a given space when it is in bulk boxes than when it is in palletized crates. For emptying, dumpers have been developed that empty the fruit with less bruising than when field crates are used (4, 6).

In 1957 about 4,000,000 bu of apples and several million bu of other fruit and vegetable crops were handled in bulk boxes. Indications are that this method of handling will rapidly expand and replace crate handling of many farm crops.

Water Handling

In 1953 the USDA, in cooperation with Michigan State University, investigated the possibility of replacing the unit containers used for handling sour cherries with bulk containers filled with water (1). This study resulted in the water method of transporting cherries. In initial experiments, the cherries were handled in lugs holding 25 to 27 lb each in the usual manner until they reached the receiving station. There they were poured from the lugs into truck-mounted tanks of water for cooling and transporting to the processing plant. Later experiments carried this idea further by transferring the cherries from the picker's pails to water-filled tanks at the orchard (Fig. 5). Doing tnis eliminated the use of lugs completely.

Tanks 4 ft by 4 ft by 4 ft of 13-gauge sheet metal are used in some orchards. They are partially filled with cold water and set under the trees. Workers pick the fruit into 10-qt pails. When their pails are full they pour the cherries into the tanks. When a tank is full, it is moved onto a trailer by means of a tractor fork lift. At the processing plant the tanks are unloaded simply by opening the valve and fluming the cherries out (Fig. 6). The truck driver usually unloads the cherries with no labor cost to the processor.

This system cuts labor cost and cost of expensive lugs. It also simplifies management and operation both in the orchard and processing plant. The quick cooling of the fruit and the cushioning effect of the water result in better quality fruit. About 35 million lb of cherries were transported in water during the 1957 season.

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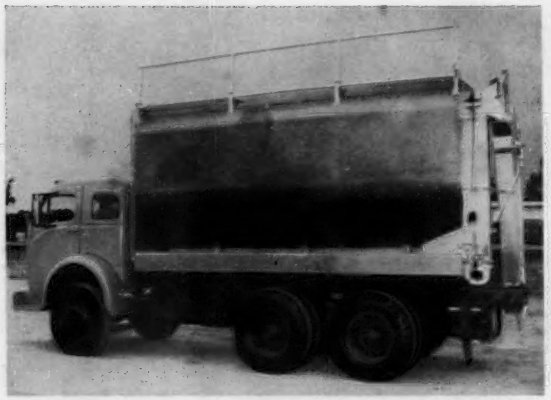

Fig. 1 Systematizing, involving integration of on-the-farm handling with off-the-farm handling, centers around bulk load carrying devices

Fig. 2 The stack mover, combined with a hay stacker, provides a satisfactory hay handling system in semi-arid areas

Handling Loads and Stacks

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IF ONE could determine the ton-miles of materials conveyed by various mechanical devices in the farm economy, there would seem little doubt that vehicular loads account for the lion's share.

The handling of loads consists of three essential phases: *(a)* loading, *(b)* traveling, and *(c)* unloading.

Until about 1945 the evolution of agricultural load carrying devices had been characterized by a primary concern for the simple act of transporting a load (travel phase). Although motive power and running gear had undergone much change since ox-cart days, the general purpose box was still the standard device. It might be found on a truck chassis, or on a farm running gear. Little, if any, provision was made for its mechanical loading or unloading. Some few specialized types of bodies such as stock racks and grain boxes did exist. The manure spreader stood alone as a generally used self-unloading vehicle on the farm.

The labor-short years following World War II brought general use of such loading and unloading devices as the farm elevator, the tractor loader, the dump box and the self-unloading forage box. Each of these was an individual piece of equipment not necessarily matched to the equipment from which it received its load, or to which it unloaded.

Systems Concept

The recent era of concern for cost reduction, convenience, timeliness, labor-saving, and product quality is bringing a new complexion to the handling of agricultural loads. The agricultural businessman is finding it desirable to acquire load handling devices which are designed within the systems concept. Much attention is being given to loading and unloading methods and to specialized vehicle forms.

The integration of various load handling devices into farm materials handling systems can be illustrated by many existing commercial machines.

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The author—C. L. MARTIN, JR.—is director of engineering research and development, The Farmhand Company, Hopkins, Minn.

In some cases this systemizing is forced by integration of on-the-farm handling with off-the-farm handling. Examples of such situations might be: *(a)* Bulk fertilizer distribution, *(b)* Bulk feed handling, *(c)* Bulk milk handling, *(d)* Handling sweet corn with high dump boxes, and *(e)* Handling alfalfa for dehydrators with large self-unloading boxes.

In other cases this systemizing stems from the integration of field processes with farmstead processes. Some examples would be: *(a)* Handling of forage crops with self-unloading wagon boxes, *(b)* Use of mechanical loaders for handling silage in pit, bunker or stack silos, *(c)* Bunk feeding of cattle with self-unloading wagon or truck boxes, and *(d)* Handling hay with stackers and stack movers.

The integration of a load-carrying device into a system oftimes imposes other functions upon it (Fig. 1). We now find load carrying devices performing such additional functions as:

(a) Metering—long accomplished by the manure spreader, and now common in feed, fertilizer, forage and other equipment.

(b) Spreading—manure and fertilizer spreaders, seeding, and feeding devices.

(c) Cleaning—some specialized sugar beet wagons.

(d) Mixing—certain types of self-unloading feeder bodies.

(e) Cooling—certain equipment used by processors for the transport of lima beans, peas, and cherries wherein the vehicle is equipped with water sprays, water tanks, or refrigeration equipment.

(f) Drying—certain commercial types of wagon grain and hay dryers.

(g) Packing—some fresh produce packers clean, grade and pack in the field on the trucks which ultimately haul the produce to the cooling plant.

The objectives which generate a given load-handling system are to be found in the realm of cost reduction, improved product quality, and work simplification. But the dominant reasons for a specific system can be any of a multitude. Similarly, the engineering approaches required are diverse.

. . . Loads and Stacks

A review of the evolution of certain systems involving load carrying devices could serve to illustrate the interplay of factors involved, as well as the specific equipment developed.

Evolution of a Hay Handling System

The handling of hay by stackers and stack movers represents one evolution of an equipment system. Stackers are in general use in the semi-arid areas where outdoor storage of hay is suitable and where traffic in commercial hay is minor. Through their use the farm operator gained the ability to construct a hay stack quickly and effectively with a machine. But he had a further need to move the stack easily to its point of ultimate use. Sundry designs of stack movers were developed on a farm shop basis. Their use became sufficiently widespread to warrant the commercial production of stack movers and several such machines are now on the market (Fig. 2).

Thus, the use of a stacker and a hay stack mover have become accepted practices and represent two machine elements of a system. Some farmers however, were still not fully satisfied with the system.

First, the construction of hay stacks by eye results in a great variation in stack size and shape. This variation is not conducive to most effective use of the stack mover. Hence the use of the hay cage was developed as a means of molding the hay stack to a desirable size and shape. It also permits the construction of the stack with less time and labor.

Second, the feeding of a hay stack in many circumstances becomes a difficult and labor demanding process, unless the stack can be located so that the cattle can self feed. Grapple forks on tractor loaders are in general use to tear apart stacks, but the process is tedious and time consuming. Hence, a fourth development in this hay handling system has been the mechanical hay stack saw. Such saws permit the operator to slice off a portion of the stack and drop it in almost any desired location on the feed lot or range. Thus the combination of stacker, hay cage, stack mover and stack saw, provides a total system of hay handling in which the load carrying device is a critical member. In appropriate conditions this system provides a high degree of versatility and probably the lowest per-ton cost of any known hay handling system.

Wagon Developments

The high dump wagon evolved from a situation in which truck costs were a governing factor. In the handling of sweet corn for canneries the general practice has been to load common straight trucks in the field directly from the mechanical harvesters. The ton-mile rates of trucks are far more economic than the use of farm wagons. They have the capability of following the corn harvester in the field under most conditions. If the processor desires to truck his crop from a greater radius however, there is a point where the use of truck-tractor and semi-trailer becomes more economic than the use of straight trucks. The truck-tractor semi-trailer cannot be loaded directly from a mechanical harvester in most conditions because of its size, weight and lack of maneuverability in the field. Hence, it becomes necessary to load the corn from the corn harvester into a farm wagon or into a straight truck. These must then be reloaded by one means or another into the semi-trailer. This reloading process is not only costly and time consuming, but also quite damaging to the product.

After some exploration it was felt that the use of a wagon which could be towed by the corn harvester to accept the load in the field, and which could then be unloaded quickly and directly into the semi-trailer, would be more economic than various re-loading schemes which had been employed.

Such wagons (Fig. 3) were developed to provide a load capacity of 3½ tons. These could be dumped at a height of

Fig. 3 High dump wagons can be towed by harvesting machines and can be unloaded quickly and directly into semi-trailers for long hauls

11½ ft in 1½ min while being operated by a common farm tractor. Five loads from such a wagon fill a common semi-trailer which is then hauled to the processor's plant.

Use of the high-dump wagon and semi-trailers has made possible the economic hauling of sweet corn over a 150-mile radius where previously the economic radius was about 50 miles.

Self-unloading forage boxes of several types have been in common use for years. Their original concept had been to eliminate the drudgery of forking silage off the wagon by providing a rear unloading conveyor. Despite this labor reduction, the wagon still required time-consuming maneuver to orient it with the forage blower. It also required much hand labor during unloading to minimize the avalanching of the load into the blower.

While these wagons were developing in popularity, they came into some use as devices for distributing forage into cattle bunks (Fig. 4). In this application they were equipped with front unloading aprons and cross conveyors. They were also equipped with beaters which broke up the avalanching of the load and helped to meter the load into the bunks. Ultimately their conveyors and beaters were developed to the point where they served not only as effective meters, but could also be used to mix ground feed with forage.

Fig. 4 Self-unloading forage boxes collect forage in the field and deliver it to silo-filling devices or cattle bunks

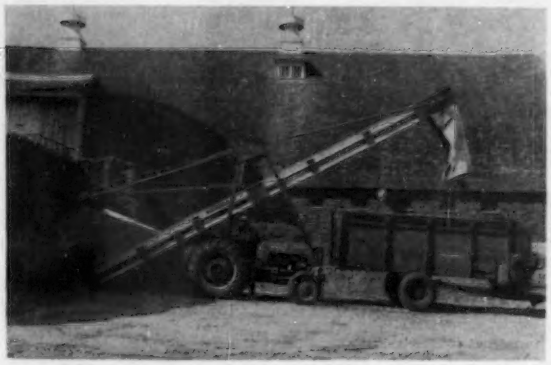

Fig. 5 Silage loader applies the principle of continuous flow to silage handling

It then became apparent that the front unloading cross conveyor is much more easily oriented to a forage blower, than is the rear unloading type of box. The metering effect was most desirable in feeding the blower. Hence there is now a trend towards using the front unloading box equipped with beaters in the harvesting of forage to be blown into vertical silos. In some operations 50 percent less man-hours have been required in the unloading process.

Bulk Handling

Commercial feed now constitutes nearly 30 percent of all feed used exclusive of pasture and roughage. There are indications that this figure may climb ultimately to 50 or 60 percent of all feed used. Until a few years ago virtually all of this feed was handled in bags.

The bulk feed truck was introduced as a means of lowering commercial feed costs by eliminating bagging and bag handling. This represents $3.00 to $5.00 per ton.

Various types of trucks are now in use. However, they have, in common, unloading devices which permit delivery of struction equipment such as clam shells has been used. These unloading devices may take the form of intricate screw and flight conveyors, or low-pressure, air-conveying systems. In all cases they permit great flexibility in distance and position of delivery point relative to the truck.

As the practice of bulk feed delivery is adopted it engenders systemizing of the farmstead equipment which it serves. Larger batch bins are required for storage. Or, if the feed is delivered directly to self-feeders, the type, size and location of the feeder must accommodate bulk delivery. Possibly the feed lot layout may require altering.

Bulk milk handling is a situation similar to bulk feed handling in that small unit batches (cans) are being displaced by larger batches (truck loads). Here again specialized truck body and loading equipment must be integrated with new and different farmstead equipment designed specifically for the system.

Stacks

The noun "stack" as used in farming has generally carried the connotation of a bulk of material piled outdoors and so large that it could not be moved in one load on available vehicles.

Stacking is a practice followed with many products. We have hay stacks, straw stacks, silage stacks; stacks of bales, bags, milk cans and pallets.

Each type of stacked material presents its own problems. The hay stack mover has altered the concept of the stack in the case of hay.

The silage stack and pit or bunker silo is also yielding to a new approach. Batch loaders such as the tractor front-end loader have been employed in rooting out material from silage stacks and loading it on trucks or wagons. In the case of the huge silage stacks built by vegetable processors, heavy construction equipment such as clam shells have been used. These batch devices all have their limitations in cost per ton moved, and in general suitability.

The silage loader (Fig. 5) applies the principle of continuous flow to the removal of stacked silage. Where substantial tonnage is to be moved, it offers a much higher "through put" at lower cost per ton than batch loaders. It offers the further advantages of reduced maneuver time for the vehicles being loaded, reduced uprooting of the stack bottom area, and reduced waste of silage in the bottom area.

These are but a random sampling of methods for handling loads and stacks. They will illustrate however, the application of the systems concept to load and stack handling.

. . . Non-Free-Flowing Materials

(Continued from page 565)

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Part II Tractor Book Available

"DEVELOPMENT of the Agricultural Tractor in the United States," Part II, by R. B. Gray is now available. This edition is a complement to Part I which included an account of the early history of the agricultural tractor with brief specifications of many of the tractors produced by manufacturers of the steam traction engine and the gas tractor and discussed mechanical farm power from its beginning to 1920. Part II covers the period of history on the development of both wheel and track-type tractors from 1920 to 1950.

The first edition of Part I was printed in 1954 by the Agricultural Engineering Research Branch, Agricultural Research Service, U.S. Department of Agriculture. Because of a demand for additional copies and its historic value, the American Society of Agricultural Engineers sponsored a second printing of Part I in 1956. In order to make both editions available, ASAE has sponsored the first publication of Part II.

Mr. Gray is a retired head of the Division of Farm Machinery, Agricultural Research Service, USDA, and is nationally known for his experience in the development of farm mechanization. Part II has been written since Mr. Gray retired in 1954.

From Field to Mill . . .

An Analysis of a Typical Materials-Handling Problem

If you need new equipment, you are paying for it. This expression is applicable to materials handling systems and to most any mechanical apparatus

Meryl L. Todd
Member ASAE

CONSIDERATION of the continual improvements to machinery, new developments and types, increased operating efficiencies, competitive practices, and changing energy and manpower costs is necessary not only for new installations but for those already in use.

To illustrate the many factors that enter into the design and selection of a materials-handling system, or its evaluation, a typical large scale combined agricultural and industrial operation – a sugar mill – will be briefly described, and one phase of the materials-handling system – the moving of cane from field to mill – will be analyzed. The example selected brings to attention the many types of handling systems that must be coordinated to satisfactorily operate such an enterprise, bearing out the significance of the opening statement.

The cane handling problem to be discussed is for a sugar mill having its own cane fields, rail transportation system, etc.

Paper presented at the Farm Materials Handling Conference sponsored by the American Society of Agricultural Engineers, Iowa State College, Ames, Iowa, September 1958.

The author – MERYL L. TODD – is consulting engineer, Todd, Hedeen & Associates, Waterloo, Iowa.

FIG. 1 – EXISTING OPERATIONS

The mill has been operating for many years in a more or less conventional manner, with no major changes in materials-handling or processing methods.

Selection of a sugar mill for this discussion was made because it illustrates the application of many materials-handling methods, and the problems and analyses to be described are typical for many other farm and industrial operations.

The situation arose whereby, under new management, it was decided to investigate the possibility of increasing production, adding a waste products plant, and of reducing operating costs, which were steadily mounting due to higher labor costs, obsolete equipment, extended operations, etc.

The mill was being operated as outlined by the flow diagram in Fig. 1. The operation centered around a railroad transportation system, with cane harvesting and materials-handling methods to fit. Re-evaluation as to efficiency, costs, and need for additional capital expenditures, regardless of increased production or the addition of other industrial facilities, was overdue.

The analysis of all materials-handling methods in use was prompted by the problem of how to transport cane efficiently from a new remote area, which for the sake of identity will be called Area A. This new area, having an estimated annual production of approximately 55,000 tons, was located about 3 miles beyond the existing rail system. The production from these fields represented about 20 percent of the total annual production.

Several methods of handling the cane were possible (See Fig. 2).

Plan A – Hand cutting, P & H loading, tractor trailer trains to railroad, rail transfer station, railroad to mill.

Plan B-1 – Area A – Hand cutting, P & H loading, tractor trailer trains to truck transfer station, trucks to rail transfer, rail transfer station, railroad to mill. Trucks on lease or hire basis.

Area B same as Plan A.

Plan B-2 – Same as B-1 except trucks owned by mill.

Plan C-1 – Area A – Hand cutting, push raking, grab loading, truck to railroad, rail transfer station, railroad to mill. Trucks on lease basis.

Area B same as Plan A.

Plan C-2 – Same as C-1 except trucks owned by mill.

Plan D-1 – Area A – Hand cutting, push raking, grab loading, trucks to factory. Trucks 6 to 8-ton capacity on lease basis.

Area B same as Plan A.

Plan D-2 – Same as D-1 except trucks owned.

Plan D-3 – Same as D-2 except trucks or trailers are 20 to 25-ton capacity each.

Plan D-4 – Areas A and B – Hand cutting, push raking, grab loading, trucks to factory owned and 20 to 25-ton capacity. Railroad eliminated.

Plan E-1 — Area A — Hand cutting, P & H loading, tractor trailer train to truck transfer, Hyster transfer station, trucks 6 to 8-ton capacity on lease basis to factory.

Plan E-2 — Same as Plan E-1 except trucks owned.

Plan E-3 — Same as Plan E-2 except trucks 20 to 25-ton capacity.

The use of any of the plans except D-4 would require an increase in rolling stock to accommodate the increase in annual tonnage and the increase in average distance from the mill.

The use of small, 6 to 8-ton sling-loaded trucks directly from the fields of Area A to the mill would necessitate combined use of the existing unloading station, which would be pressed for increased capacity. Also, there would be a delay in the unloading of rail cars proportionate to the amount of cane received by small trucks. The disruption of rail car movement would extend the field loading period unless additional cars were provided, requiring additional capital expenditure.

If sling loaded, the use of large trucks would present the same problem at the unloading station. With bulk-loaded large trucks, a different unloading facility would be required at the mill station.

A change in field loading procedure, from mechanical grab loading from the windrow to tractor-drawn trailer units to a push rake system, would result in additional trash and dirt being carried to the mill. This in turn would require increased clarification and filtering as well as additional mill capacity, which must be considered in the evaluation of the handling system.

The final decision to be made, once the most efficient system for the new Area A had been determined, was whether or not to convert the entire plantation operation to a single type system, or to use the existing rail facilities plus the equipment necessary to handle the production of Area A.

The over-all materials-handling system finally selected for the entire agricultural and industrial application, using a mechanized cane hauling and transportation system, was as shown in Figs. 3A and 3B. Factors influencing the selection will be summarized to the extent that time and space permit.

Each of the many types of material handling involved in the farm and plant operation required a detailed analysis in itself. For example, included on the project were:

Fields
- Mechanized push rakes
- Crane grab hoist loaders
- Special cane hauling units

Transport
- Rail and truck or tractor trailer

Receiving and Unloading
- Truck (bulk) unloading hoist
- Tower crane
- Heavy tonnage chain and slat auxiliary conveyors
- Cane carriers—chain and wood slat conveyors
- Cane carriers—chain and steel slat conveyors

Mill
- Intermediate conveyors—chromal steel chain
- Bagasse conveyors—steel chain and vertical slat
- Juice drainer conveyors—drag type
- Pneumatic conveyor for bagacillo
- Ash removal system—drag conveyor
- Feeder conveyors

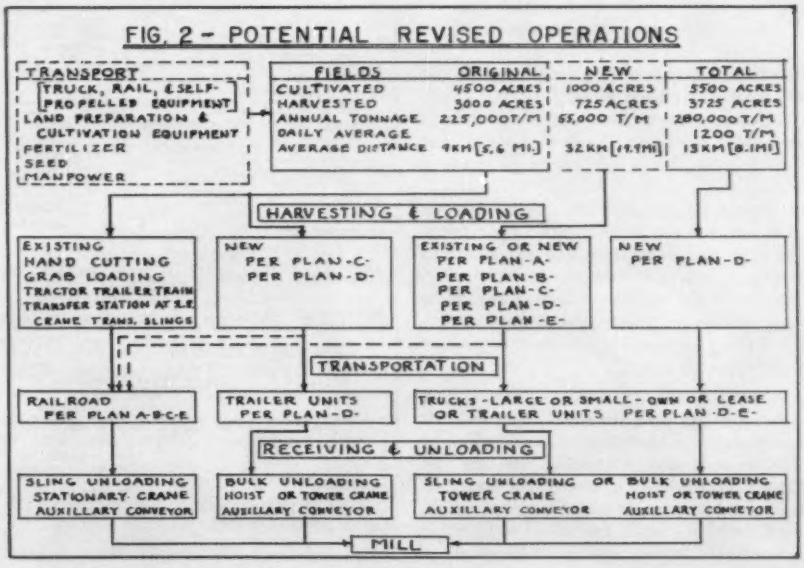
Elaboration Plant
- Liquid conveying, weighing and liming system
- Screw conveyors
- Vibrator conveyors
- Bulk sugar elevators
- Dump car system for sludge and filter waste

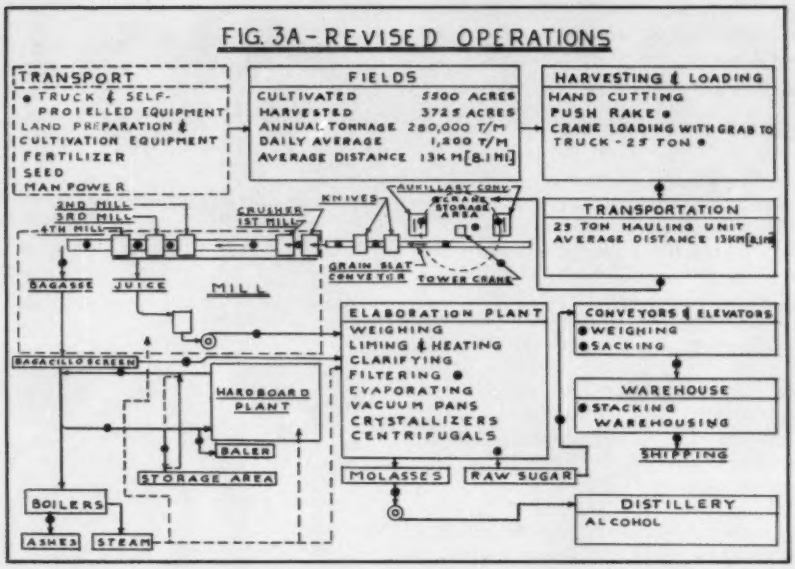
Sugar Warehouse
- Weighing and sacking system
- Bag stackers and conveyors

Board Plant
- Bagasse conveyors—chain and vertical slat
- Screw conveyors
- Drainer conveyors—drag type
- Fibre conveyors—liquid
- Pulp conveyors—pneumatic
- Forming machine and press roll roller conveyors
- Dryer conveyor—special chain and roller type
- Powered roller conveyors
- Lift trucks
- Jib cranes
- Overhead traveling cranes
- Grab load cranes
- Bale handling system
- Rail car system for baled bagasse
- Refuse systems—pneumatic

The general procedure followed and some of the analyses involved in the problem of handling the raw material from the field to the mill will be discussed To avoid a lengthy presentation, summaries only are included in most instances.

FIG. 2 - POTENTIAL REVISED OPERATIONS





Mill Unloading and Receiving Station

The existing system of unloading at the mill was a "bottleneck". Provision of a uniform supply of cane to the mill and the resulting release of rail cars to the fields were desirable, and it was hoped that a solution to this problem would also fit any future revision in the cane transport system from the fields to the mill.

This was accomplished by the utilization of a tower crane and the installation of additional and improved conveyors (Fig. 4).

By installing a tower crane at the unloading station, the crane having an operating height of 40 ft, a circular traverse of 120 ft and a lifting capacity of 5 tons, the following operations were possible:

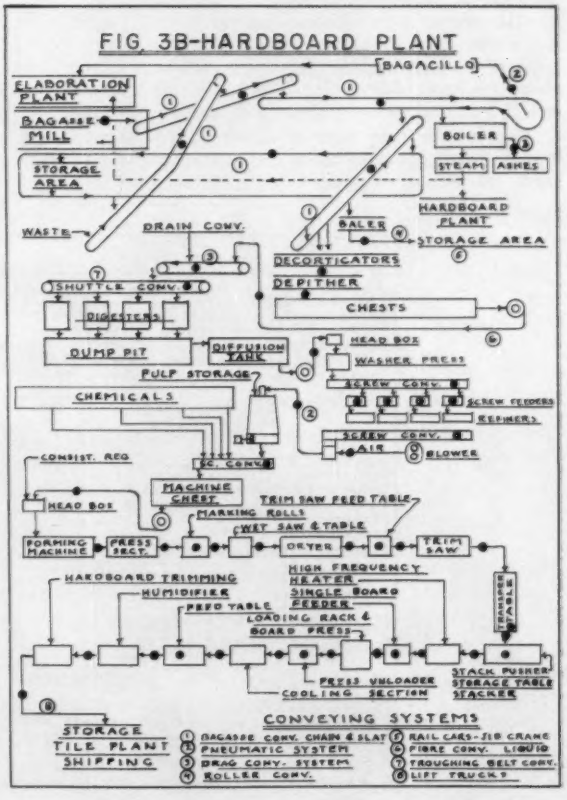
(a) Rail transport — sling loads — The crane supplements the car unloading at the station, relieving the pressure on the existing donkey crane, thus assuring a continual minimum quantity of cane to the mill cane carrier. In addition, with added unloading facilities it is possible to stockpile cane for supply to the mill during interrupted or irregular transport of cane to the mill.

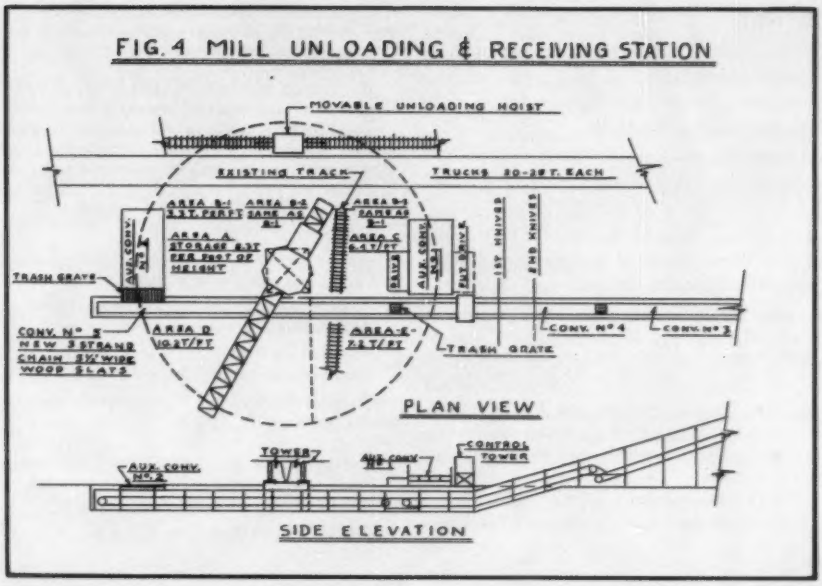
With increased transport and unloading facilities, it is also possible to stockpile cane for week-end milling without operation of the field or transport system. This is accomplished by a rotating stockpile system, so that no cane is delayed over 24 hr before entering the mill. Longer delays could result in some inversion of sugar.

Assuming a 1200-ton per day mill capacity, an accumulation of 1200/6 days = 200 tons per day is necessary, or the transporting to the mill of 1400 tons daily. The first day a surplus of 200 tons is left to be milled (first) on the second day. A surplus of 400 tons exists at the end of the second day, to be milled on the third day, and so on. At the end of the sixth day 1200 tons remain for milling on the seventh day—cane which has not been stockpiled over 24 hours.

(b) Rail transport and sling-loaded trucks — Where both systems are used for transporting cane, the tower crane unloads the trucks so as not to disrupt the normal rail car unloading by the donkey crane. It unloads and stockpiles from the rail cars, and transfers from the stockpile to one of the live auxiliary conveyors. This procedure releases rail cars more rapidly, and minimizes or eliminates the need for additional rolling stock or longer periods of field loading due to car shortage.

(c) Bulk truck transport — If the decision is made to eliminate the railroad, and to replace it with large capacity bulk cane hauling units of 20 to 25-ton capacity, which system on the basis of the study appears to be the most economical, the donkey crane is to be replaced by a special truck unloading hoist. The large trucks are designed with no bottoms except a series of chains on approximately 2-ft centers. The chains are





permanently attached to one side of the trailer body (the body is approximately 8 ft 6 in. high, 10 ft wide and 35 ft long for a capacity of 25 tons), and are attached on the opposite side to a channel extending the full length of the truckside. This channel is removable and is hoisted vertically by the special hoist to a point where the cane spills over the side to which the chains are permanently attached. The arrangement is such that the chain assembly acts as a huge net. One advantage of this arrangement is the ability to unload along side of the truck on ground level, without the construction of pits or ramps. Also, the open bottom permits some loss of dirt and trash.

The tower crane is used to transfer the unloaded bulk cane, by means of a grab hook assembly, either to a stockpile or directly to one of the two auxiliary conveyors. Conveyors can be loaded by the tower crane at a rate much greater than required by the mill cane carrier. The carrier operator regulates the speed of either auxiliary conveyor to fulfill the requirements for a uniform supply of cane to the mill.

The truck unloading, transfer to the auxiliary conveyor and discharge to the main cane carrier also serve the function of additional dirt and trash removal.

Cane Cutting, Loading and Transporting

The handling of the cane in and from the fields involved evaluation of the existing rail system, the type, design and arrangement of cane hauling units, and methods of loading in the fields.

Rail System:

Essentially the railroad system consisted of 30 miles of main track, plus spurs and switches, nine locomotives, 44 cane cars of 10 and 20-ton capacity, and two steam donkey cranes.

The average engine hauling capacity was 80 tons, running at a speed of 21 mph empty and 12 mph loaded.

The average cost per ton mile was 5.3¢, or a cost per ton of cane hauled of 47.7¢. This cost covered operation, maintenance and repairs to the system.

The hauling distance from field to mill averaged 5.4 miles.

Truck or Trailer System 6 to 8-Ton Capacity Trucks:

(a) Lease Trucks—It was estimated that to handle Area A at the rate of 400 tons per day, 20 tons per hour, eight to ten trucks with capacity of 6 to 8-tons would be required.

Theoretically, with bulk loading and a capacity of 8 tons per truck, only six units would be required. Ten were suggested, since some truck and body designs do not have sufficient volume.

Experimental use of leased trucks, but sling-loaded, resulted in an average ton-mile cost of 5¢ for an average distance to the mill of 12 miles. While this cost per ton-mile should be reduced with experience, elimination of slings, and better field equipment, the unit cost above is used so as to offset body repair, special bodies, repairs due to accidents, etc.

(b) Owned Trucks—The comments with regard to leased trucks apply to owned trucks, except that a lower operating

TABLE 1. HAULING UNIT CAPACITY—25-TON LOAD

Distance round trip, miles	Speed mph	Running time, min	Total* trip time, min	Efficiency of operation, percent	Tons per hour	No. Units 16.7†	33.4†	50†
3.0	12	15.0	45.0	80	26.7	0.625	1.25	1.875
	15	12.0	42.0		28.6	0.605	1.17	1.775
	18	10.0	40.0		30.0	0.558	1.113	1.671
	21	8.6	38.6		31.2	0.537	1.07	1.607
	24	7.5	37.5		32.0	0.520	1.04	1.56
6.0	12	30.0	60.0	80	20.0	0.835	1.670	2.50
	15	24.0	54.0		22.2	0.752	1.504	2.25
	18	20.00	50.0		24.0	0.695	1.390	2.08
	21	17.15	47.15		25.4	0.658	1.316	1.97
	24	15.0	45.00		26.7	0.625	1.250	1.87
10.8	12	54.0	84.00	80	14.3	1.17	2.34	3.49
	15	43.2	73.20		16.4	1.02	2.04	3.05
	18	36.0	66.00		18.2	0.92	1.84	2.71
	21	30.9	60.90		19.75	0.846	1.69	2.53
	24	27.0	57.00		21.00	0.797	1.594	2.38
15.6	12	78.0	108.00	80	11.10	1.50	3.00	4.5
	15	62.4	92.4		13.00	1.285	2.570	3.84
	18	52.0	82.0		14.6	1.17	2.34	3.49
	21	44.6	74.6		16.1	1.04	2.08	3.10
	24	39.0	69.0		17.4	0.962	1.924	2.87
38.4	12	192	222	80	5.40	3.09	6.18	9.25
	15	154	184		6.53	2.56	5.12	7.65
	18	128	158		7.60	2.20	4.40	6.58
	21	110	140		8.58	1.95	3.90	5.83
	24	96	126		9.50	1.76	3.52	5.25

*Includes 30 min fixed time (15 min to load, 10 min to weigh, 5 min to unload).
†Tons per hour.

. . . Field to Mill

cost per ton-mile is anticipated, due to better maintenance of trucks and better-trained operators.

A ton-mile cost for owned 6 to 8-ton capacity trucks with locally built bodies is estimated at 4.5 cents.

20 to 25-Ton Capacity Trucks:

Analysis of Requirements — Three typical cases will be summarized to illustrate the effect of method of harvesting, selection of hauling units, and the data essential for estimating operating costs. Table 1 shows capacities and number of units required for various running speeds, distances and capacities.

Case 1 — 280,000 metric tons to handle, season 234 days, average hauling distance 8 miles.

A — 55,000 tons to be harvested in not more than 137 days at the rate of 400-metric tons per day. The distance to the mill averages 19 miles.

From Table 1, using an average round trip speed of 21 mph for a total distance of 38 miles, 1.95 units of 25-metric-ton capacity are required.

Total trips = 55,000/25T = 2200

Total mileage = 2200 × 38 = 83,600 miles

Total trip time for 137-day season = 2200 × (110 min + 30)/60 = 5133 hr

Total running time for 137 days = 2200 × 110 min/60 = 4033 hr

Total available hours per day = 24 × 0.80 Eff. = 19.2 hr

Max. trips per day per unit = (19.2 hr)(60 min)/(110 + 30 min) = 8.14

No. trips required daily = 400T/25T = 16

B — 110,000 tons must be handled during the above 137 days at the rate of 800 tons per day minimum in order to maintain a minimum of 50 metric tons per hour milling rate. The average distance from the fields producing the 110,000 tons to the mill is 5.4 miles.

From Table 1, using an average running speed of 21 mph for a total distance of 10.8 miles, 1.69 units of 25-metric-ton capacity are required. Trips, mileage, running time, etc. are calculated as for A.

During the 137 days, to handle 165,000 tons:

No. of units = (A) 1.95 + (B) 1.69 = 3.64

Total trips = (A) 2200 + (B) 4400 = 6600

Total mileage = (A) 83,600 + (B) 47,520 = 131,120 miles

Total trip time = (A) 5133 + (B) 4470 = 9603 hr

Total running time = (A) 4033 + (B) 2270 = 6303 hr

Total available hours = (137)(24)(.80) = 2630 hr

C — 115,000 metric tons must be handled in the remaining 97 days of the 234-day annual season at a rate of 1200 metric tons per day to maintain an hourly milling rate of 50 tons per hr. The average distance to the mill is 5.4 miles.

From Table 1, using an average running speed of 21 mph for a total distance of 10.8 miles, 2.53 units of 25-ton metric-ton capacity are required. Trips, mileage, running time, etc. are again computed as for A.

During the 234-day season, to handle 280,000 metric tons for the conditions A, B and C under Case 1:

No. units = 1.95 + 16.9 = 3.64 for 137 days
2.53 for 97 days

Total no. trips required = 2200 + 4400 + 4600 = 11,200

Total mileage = 83,600 + 47,520 + 49,680 = 180,800 miles

Total trip time = 5133 + 4470 + 4670 = 14,273 hr

Total running time = 4033 + 2270 + 2370 = 8673 hr

Total available hours = (234)(24)(80 percent Eff.) = 4490 hr

Using four hauling units of 25-ton load capacity at an average running speed of 21 mph for the annual harvest of 280,000 tons per Case 1:

Mileage per unit (avg) = 180,800/4 = 45,200 mile each

Hours running time = 8673 hrs/4 = 2168 hr each

Hours in use = 14,273 hr/4 = 3568 hr each

Case 2 — 280,000 metric tons to handle in 234 days, average distance to mill 7.8 miles at a minimum rate per day of 1200 tons.

From Table 1, using an average speed of 21 mph for a total distance of 15.6 miles, 3.10 units of 25-metric-ton capacity are required. Trips, mileage and running time are computed as for A under Case 1.

Case 3 — 280,000 metric tons to handle, season 234 days

A — 55,000 tons to be handled at rate of 1200 tons per day at distance from mill of 19.2 miles. No. of days = 55,000/1200 = 45.8.

From Table 1, using an average round trip speed of 21 mph for a total distance of 38.4 miles, 5.83 units of 25-metric-ton capacity required. Trips, mileage, running time, etc. are calculated as for A under Case 1.

B — 225,000 tons to be handled at rate of 1200 tons per day, 187.5 days, at an average distance from mill of 5.4 miles.

From Table 1, using an average speed of 21 mph for a total distance of 10.8 miles, 2.53 units of 25-metric-ton capacity required. Trips, mileage, running time, etc. are calculated as for A under Case 1.

During the 234-day season, to handle 280,000 metric tons from Area A and Area B as described above under Case 3:

No. units = A = 5.83
B = 2.53

Total no. of trips = 2200 + 9000 = 11,200

Total mileage = 83,600 + 97,200 mi. = 180,800 miles

Total trip time = 5133 + 9140 = 14,273 hr

Total running time = 4033 + 4640 = 8673 hr

Total available hours = (234)(24)(.80) = 4490 hr

Using six hauling units of 25-metric-ton capacity each, at an average running speed of 21 mph for the total harvest of 280,000 tons per Case 3:

Mileage per unit (avg) = 180,800/6 = 30,133 miles each

Hours running time = 8673/6 = 1445.5 hr each

Hours in use = 14,273/6 = 2329 hr each

Summarizing the three Cases, 1, 2 and 3:

	Case 1	*Case 2*	*Case 3*
Mileage per unit	45,200	43,650	30,133
Hours running time	2,168	2,088	1,445.5
Hours in use	3,568	3,485	2,329
Number of units (25-ton capacity)	4	4	6
Total available hours	4,490	4,490	4,490
Hours in reserve	928	1,005	2,161

From the above summary it is readily noted that scheduling of fields to be cut at a given time determines the number of units required. Operating costs per ton-mile will vary with the length of haul due to the fixed time for loading, weighing and unloading. The average ton-mile operating cost per year should remain more or less constant, but will be influenced by the number of units owned.

The studies in all cases are likewise made for running speeds other than 21 mph in order to make a comparison of operating costs versus capital investment under varying hauling conditions.

It is important also to evaluate the use of larger or smaller capacity hauling units. In this study only 25-ton units have been mentioned, since in the over-all analysis of the handling system it was found that for field diversity, minimum continuity of mill operation, maximum operating efficiency and economy, larger or smaller units were less desirable.

In the actual selection of the hauling units, additional factors must be considered, such as

Single axle tractor units
Double axle tractor units
Multi wheel large trucks
Large tires versus small tires
Type of roads and field conditions
Availability of maintenance and spare parts
Etc.

In determining the most economical type hauling unit, a comparison of owning and operating costs would be desirable.

Having established the various unit operating costs for loading and transport equipment and for the field operations, a comparison could then be made of the various plans heretofor listed.

Also, it would be necessary to determine the capital expenditures necessary for new or additional equipment for the

various plans. By consolidating these figures with those estimated for operating and maintenance, a summary of all costs could be tabulated, as per Table 2. The comparative costs per ton of material handled would then be available.

On the basis of the final figures, it is apparent that the railway system and the present material handling methods should be replaced by a more economical system, as outlined in Plan D-4. The use of the plans involving the railroad would mean that "If you need new equipment, you are paying for it," whether or not it is installed.

TABLE 2. TOTAL ANNUAL COST (DOLLARS), 280,000 METRIC TONS, 20-HOUR DAY

	Capital Expenditures	Depreciation per year*	Operating and maintenance cost	Total	Cost per ton
Plan A					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	62,100.00	12,420.00	———		
		44,620.00	301,560.00	346,180.00	1.236
Plan B-1					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	42,000.00	8,400.00	———		
		40,600.00	358,120.00	398,720.00	1.424
Plan B-2					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	54,000.00	10,800.00	———		
		43,000.00	346,920.00	389,920.00	1.392
Plan C-1					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	109,000.00	21,800.00	———		
		54,000.00	296,520.00	350,520.00	1.252
Plan C-2					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	121,000.00	24,200.00	———		
		56,400.00	285,320.00	341,720.00	1.220
Plan D-1					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	70,000.00	14,000.00	———		
		46,200.00	252,400.00	299,600.00	1.070
Plan D-2					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	130,000.00	26,000.00	———		
		58,200.00	244,440.00	302,640.00	1.080
Plan D-3					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	140,000.00	14,000.00	———		
		46,200.00	231,840.00	278,040.00	.993
Plan D-4					
Railroad (existing)	———		———		
Expenditures (new)	245,000.00	27,500.00	———		
		27,500.00	179,200.00	206,700.00	.738
Plan E-1					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	35,000.00	7,000.00	———		
		39,200.00	316,400.00	356,600.00	1.273
Plan E-2					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	65,000.00	13,000.00	———		
		45,200.00	307,440.00	352,640.00	1.259
Plan E-3					
Railroad (existing)	———	32,200.00	———		
Expenditures (new)	105,000.00	21,000.00	———		
		53,200.00	294,840.00	348,040.00	1.243

*Grader and trailer unit depreciation has been included in operating maintenance cost

. . . Silage Handling

(Continued from page 557)

structures have top mechanical unloaders. In structures having larger diameters, a small tractor is used to push silage to the openings.

A mechanical bottom unloader for the air-tight glass-lined storage structure utilizes a rotating cutting arm to move the silage. A bottom unloader permits a continuous flow of materials in and out of storage. First silage in is the first to be unloaded. Material added on top during subsequent fillings is the last to be removed.

Power requirements for chopping, filling, and unloading equipment have been upped without regard to where such power is coming from. We have followed an industrial trend prevalent for many years — we overcome problems by increasing horsepower input rather than by refining machinery to use a minimum of horsepower. This trend seems to be changing.

In designing new equipment, evaluate those power sources that are universally available and determine if the new equipment will work with these power sources. Then the right motor will be specified for the equipment and the horsepower requirements will be kept to a minimum.

Feeding the Silage

Methods of feeding silage after it is unloaded from the structure are receiving their share of national attention. Until recently, mechanized feeding was basically a silage conveyor to move the silage from one point to another. Now the fundamental object is to blend grain, concentrates, and silage in the correct proportions into one main conveyor to deliver a complete ration to the livestock. Buyers of mechanized feeding equipment now demand a complete feeding system rather than just a feed conveyor.

Most of the first mechanized feeding units were based on the shuttle stroke or the continuous chain and paddle barn cleaners. Often the farmer designed and made his own equipment. Next came equipment designed especially for silage feeding. Out of this came the Lazy Susan feeder, feed carts, chain conveyors, and augers.

I would estimate that at least 75 percent of all automatic silage feeding equipment in use today is based on the auger system. There is good reason for this. The auger conveyor will transmit both forages and grains. Maintenance is low. It has the ability to go around corners engineered into it. It requires the lowest initial investment of most feeding systems. By no means am I stating that the auger conveyor is "the" system. But customer acceptance rates it high at the present time. No doubt developments could make this an obsolete statement in a matter of two or three years.

What Does the Buyer Want?

What is the buyer of automatic feeding equipment seeking in his feeding system? Flexibility probably is the key word.

To be flexible a system must be reasonably long lived and have a high capacity. It must be quiet, stop automatically when the feed bunk or feeder is full, and be able to blend ingredients (both grain and supplement) with silage in any required proportion. The feeding system must not segregate feed as it carries it along and delivers it to the feed bunk. Wind should not carry the feed away as it drops to the bunk. The feeder should adapt to fence line feeding. It should be easy to regulate the amount of silage in the feed bunk. With all these features, the farmer will have a system he can rely on for a complete feeding job.

Mechanized feeding of silages as part of a complete feeding system may become increasingly important. Indications are that it is better to feed less at one time but feed several times during the day and night. Many feeders and researchers feel that multiple feeding increases feeding efficiency coefficient. Your estimate is as good as mine on how popular such a feeding program will become. This feeding program could be done by hand, but farmers are not going to do it.

In the whole silage handling field, development work should continue. We need to make cutting, conditioning, and wind rowing a combined operation. A short cut forage and continued work on filling and distributing equipment is my recommendation. Feeding equipment must be a total feeding system and flexible enough to adapt to changes of expansion. Silage handling equipment is good today, but tomorrow it will be better.

Radiation Papers Requested

The ASAE Committee on Radiation is soliciting papers on the application of nuclear or accelerator radiation to agricultural engineering problems, for presentation at the 5th Nuclear Congress, to be held at Cleveland, Ohio, April 5 to 10, 1959. A 300 to 500-word summary of the paper should be submitted to the committee chairman, J. K. Jensen, John Deere Research and Engineering Center, P.O. Box 270, Waterloo, Iowa, prior to Sept. 30, 1958. Any application of nuclear science as applied to agricultural engineering will be considered to be a suitable subject.

New Publication

A new technical journal, entitled *Wear*, has been announced by Elsevier Publishing Co., Amsterdam. The aim of this new publication is to report on basic research on friction, lubrication, and wear, and the application of the results to industry.

The first three issues (August, October and December, 1957) and the titles of papers now being prepared for publication cover the field of wear research, ranging from physical-theroretical studies to industrial aspects. Original papers as well as critical review articles deal with frictional properties and wear-resistance of metallic, inorganic and organic materials under laboratory and working conditions. This exchange of knowledge in English, French and German from Australia, Japan, India, the Soviet Union, United States and Europe, is supplemented by a section containing abstracts and brief reports on current events.

Winter Meeting Changes

The Chicago location for the coming Winter Meeting, December 17-19, has been changed to the Palmer House on a temporary one-year trial basis to determine advantages and disadvantages of a downtown location.

Easy access to eating places and shopping districts, special hotel room rates, and convenience for those traveling by train or plane, were given as desirable features of the new meeting site. A special flat rate plan for members who wish to share hotel rooms with others is available.

The meeting this year also was changed to the latter part of the week, falling on Wednesday, Thursday and Friday.

CORRECTION. C. W. Saldeen's position was erroneously reported in the August issue. As of July 1 he has been associated with the merchandising department of the Tractor & Implement Division of Ford Motor Co.

Joseph D. Hovanesian has accepted a position as assistant professor of agricultural engineering at Pennsylvania State University. He formerly was associated with Michigan State University as graduate assistant in agricultural engineering.

Lawrence A. Myers, Jr., formerly associated with New Holland Machine Co. as a designer, has accepted a position in the engineering department of Chore Time Equipment Inc. of Milford, Ind.

William E. Wayland has been promoted to the position of sales manager of the automotive original equipment division, Dayton Rubber Co., and has transferred from Chicago to the Detroit branch. His office will be located in the New Center Building.

Thomas E. Farrell has been promoted to industrial original equipment regional manager of the Chicago Branch of Dayton Rubber Co. He was previously sales engineer.

William D. Hanford, until recently associate editor of *Farm Implement News*, has accepted a position in the Farm Bureau of Portland Cement Association, Chicago.

Stanton R. Morrison, a graduate student at the University of California, has been awarded honorary membership in the Most Excellent Order of the British Empire in Queen Elizabeth's 1958 Birthday Honors List in recognition of his four years work in improving the rice production methods in British Honduras.

Gerald E. Thierstein, until recently a research engineer with Caterpillar Tractor Co., is now located in Saigon, Vietnam, on USOM in connection with the American Embassy.

Richard W. Smith has been transferred to the Chicago Branch of The Fafnir Bearing Co. Previously he was located in Moline as their sales representative.

Price Hobgood has been named to head the Texas A. and M. College system's department of agricultural engineering, effective September 1. He succeeds Fred R. Jones who has accepted full retirement after 38 years of service, of which 18 years he spent as head of department.

Mr. Hobgood joined the department in 1939 as an instructor and became a full professor in 1950. From 1942-46 he served in the U.S. Army Air Force from which he was discharged a captain. In addition to teaching Mr. Hobgood is widely known for his specialty of farm electrification. He has been a full time project director for the Texas Farm Electrification Committee for several years, and was appointed by Secretary of Agriculture Ezra T. Benson as a member of the U. S. Department of Agriculture's Farm and Home and Structures Research Advisory Committee and now is chairman. Also he has been active in agricultural research as a member of the Southern Rural Housing Technical Committee.

A native of Erath county, Texas, Mr. Hobgood graduated from Stephenville High School in 1929, and after one year at John Tarleton Agricultural College attended Texas A. and M. where he received a B.S. degree in 1938 and an M.S. degree in 1940.

John R. Carreker has been appointed as research liaison representative for the Soil Conservation Service and the Agricultural Research Service in nine Southeastern States.

Mr. Carreker, who has been director of the Southern Piedmont Conservation Experiment Station of USDA's Agricultural Research Service at Watkinsville, Ga., will be headquartered at Barrow Hall, University of Georgia, Athens, and will work in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Tennessee. His new duties are to inform Soil Conservation Service technicians on research findings in soil and water conservation, and to present the agency's research needs to the Agricultural Research Service.

Mr. Carreker was graduated from Alabama Polytechnic Institute, Auburn, with B.S. and M.S. degrees in agricultural engineering. He completed a 2-year training course in Rural Electrification with the

PRICE HOBGOOD

J. R. CARREKER

Westinghouse Electric and Mfg. Co., in 1932 and served as engineer and later superintendent of CCC camps doing erosion control work in Alabama in 1933 and 1934.

From 1934 to 1938 he was agricultural engineer on soil conservation demonstration projects in Alabama. On August 1, 1938 he joined the staff of the Southern Piedmont Conservation Experiment Station at Watkinsville, as agricultural engineer. He served in that capacity until July 2, 1955, when he became station director.

He is a Fellow of ASAE and currently is serving as chairman of the Soil and Water Division, member of the 1958 nominating committee, and member of the 1958-59 meetings committee. He has been a member of ASAE since 1931 and has served on various committees in the Soil and Water Division. He has also served as vice-chairman of the Southeast Section and chairman of the Georgia Section.

He reports that his agricultural engineering background was a major factor in his selection for the new position.

Glen E. VandenBerg, formerly a graduate research assistant in agricultural engineering at Michigan State University, has accepted a position with the National Tillage Machinery Laboratory of Auburn, Alabama.

Guy E. Woodward has completed an assignment as chief engineer with New Holland Pty., Ltd. in Dandenong, Victoria, Australia, and will resume employment at New Holland Machine Co. in New Holland, Pa.

Materials Handling Product Directory

This Materials Handling Product Directory has been prepared as a check list and guide in ordering materials and equipment especially adapted to the construction of materials handling equipment and systems. The numbers following the products listed below refer to the firms listed in the directory starting on page 580

Augers — 4 12, 23, 31, 36, 38, 63, 64, 96, 109, 126, 165

Bale loaders (field — hay or straw) — 5, 38, 52, 87, 109, 130

Barn cleaners — 21, 66, 81, 82, 113, 176

Barn equipment:
- Hay forks (slings, grapple) — 82, 94, 113, 115, 130, 162
- Bale conveyors — 52, 109
- Self feeders — 63, 64, 182
- Track — 82, 113, 130
- Trucks or carriers — 82, 113
- Feed carts — 66

Bearings (See conveyor components)

Blowers — 4, 5, 23, 36, 42, 52, 68, 70, 72, 91, 124, 126, 132, 155, 170

Bodies, trailer and truck — 32, 45, 61, 72, 114, 126, 151, 170, 191

Boxes — 12, 72, 81, 145, 170

Buildings and materials — 18, 19, 29, 48, 54, 64, 112, 159, 174

Casters — 13

Chain and chains — 1, 86, 96, 100, 118, 162, 187

Controls:
- Electrical — 68, 70, 133, 145
- Pressure gages — 173
- Solenoid valves — 68
- Cutouts— 16
- Push-pull — 17

Conveyors:
- Air-lift, pneumatic — 70, 170
- Apron — 7, 8, 16, 37, 47, 80, 86, 108, 129, 132, 157
- Belt — 7, 8, 12, 16, 25, 31, 38, 47, 68, 76, 80, 86, 112, 129, 139, 157
- Bucket — 12, 16, 37, 47, 68, 76, 80, 86, 112, 140, 157, 192
- Chain drag or flight — 5, 7, 12, 16, 23, 25, 30, 31, 38, 42, 47, 52, 68, 75, 86, 89, 108, 109, 125, 137, 155, 157, 162, 180, 192
- Roller—1, 7, 8, 12, 25, 31, 37, 47, 129, 157
- Screw or spiral — 7, 12, 38, 47, 68, 81, 86, 109, 140, 154, 176
- Trolley or overhead — 37

Conveyor components:
- Augers — 12, 36, 63, 68, 96, 109, 112
- Bearings — 3, 7, 12, 15, 24, 47, 57, 59, 62, 63, 67, 68, 76, 86, 96, 109, 123, 157, 166, 167
- Belting — 7, 12, 13, 36, 63, 68, 76, 80, 96, 139, 141, 163, 165
- Buckets—12, 36, 47, 68, 76, 80, 86, 96, 157
- Chains — 1, 8, 12, 57, 68, 76, 86, 96, 100, 109, 118, 187
- Clutches — 12, 20, 35, 47, 57, 68, 86, 96, 118, 122, 144, 145, 187
- Controls — 12, 16, 17, 68, 96, 145
- Drive units — 12, 13, 16, 47, 68, 79, 86, 96, 109, 122, 145, 157, 187
- Idlers — 7, 12, 23, 24, 47, 68, 80, 86, 96, 109, 123, 157
- Pillow blocks — 7, 12, 23, 47, 57, 68, 80, 86, 96, 123, 157
- Pulleys — 7, 8, 12, 13, 23, 36, 47, 57, 68, 76, 80, 86, 96, 109, 157
- Rollers—1, 7, 8, 12, 47, 68, 76, 93, 96, 157
- Shafts — 7, 12, 23, 47, 68, 76, 86, 96, 145, 157
- Sheaves — 7, 13, 24, 36, 47, 57, 68, 76, 86, 96, 145
- Speed reducers — 7, 12, 13, 16, 36, 47, 57, 68, 80, 96, 109, 118, 145, 157, 183
- Sprockets — 1, 7, 8, 12, 15, 23, 24, 47, 57, 68, 76, 86, 96, 145, 187
- Transmissions, power — 13, 79, 86, 96, 118, 139, 145, 183
- Takeups — 96

Counters — 177

Couplings, flexible — 184

Couplings, shaft — 96

Cranes — 22, 32, 52, 88, 97, 101, 145, 172, 191

Dairy equipment:
- Bulk tanks and coolers — 53, 60, 107, 188
- Pipelines — 53, 64, 175
- Milk house equipment — 53, 64, 82, 130, 175, 181
- Parlors or stalls — 53, 64, 82, 113, 130, 175
- Feeding systems — 12

Drags (crib) — 30, 76

Draintile and fittings — 28, 106, 127

Draintile laying machines — 178

Driers and fans, crop or grain — 2, 10, 29, 40, 49, 52, 68, 124, 132, 136, 152, 159

Earth moving equipment:
- Scrapers — 5, 52, 84, 101, 115, 129, 145, 186
- Shovels — 5, 52, 78, 97, 98, 101, 114, 191

Endgates, elevating — 191

Engines and power units — 5, 30, 42, 43, 52, 68, 79, 90, 109, 112, 129, 190

Ensilage distributors — 109, 152

Feeders, stock (bunk, circular, etc.) — 12, 21, 50, 64, 65, 66, 69, 82, 103, 109, 114, 124, 125, 131, 152, 170, 182

Feed mixers and blenders — 36, 50, 52, 81, 103, 111, 112, 119, 131, 132, 140, 152

Feed processing equipment — 4, 23, 36, 39, 42, 50, 68, 103, 111, 132, 135, 180
- Grinders — 4, 42, 132, 137
- Crushers — 23
- Pellet mills — 39
- Rollers — 50, 135, 137

Feed tanks — 29, 38, 45

Flexible shafts — 158

Fork lifts (see Trucks, industrial)

Gear boxes — 183

Grabs — 98

Grain bins and tanks — 12, 29, 36, 38, 45, 48, 68, 76, 124, 148

Hitches, tractor — 77

Hoists — 9, 23, 32, 68, 101, 114, 145, 150, 157, 191

Hoists for dumping trucks — 49, 96, 98

Hydraulic equipment:
- Pumps — 9, 32, 65, 68, 83, 114, 116, 145, 172, 179, 185, 189, 191, 192
- Cylinders — 32, 34, 46, 49, 55, 65, 68, 83, 114, 125, 138, 152, 171, 172, 179, 180, 189
- Motors — 83
- Valves — 32, 65, 68, 114, 116, 145, 172, 179, 185, 189, 192
- Hose — 32, 65, 68, 101, 114, 139, 141, 192

Irrigation equipment:
- Systems — 6, 14, 58, 117, 136, 164, 182
- Sprinklers — 58, 117, 120, 153, 178
- Valves — 14, 58, 117, 136, 164, 182
- Measuring flumes — 164
- Moisture meters — 85
- Pipe — 14, 117
- Couplers — 58

Jacks — 55, 145, 172

Land forming equipment:
- Back hoes — 5, 78, 97, 145, 191
- Ditchers — 5, 52, 88, 145, 178, 191
- Dozers — 5, 52, 78, 145, 191
- Graders — 5, 52, 84, 101, 145, 180
- Levelers — 52, 65, 84, 101, 105, 115, 145, 180, 186

Lifts—13, 22, 32, 71, 101, 137, 142, 145, 172

Loaders and loader attachments, tractor — 5, 52, 65, 73, 78, 98, 114, 125, 129, 152, 157, 160, 161

Lubricators, automatic — 95

Monorails — 16, 130

Motors, electric — 30, 36, 64, 68, 76, 112, 134, 165

Oil seals — 121, 128

Pallets or skids — 61

Pipe and tubing — 6, 14, 76, 112, 117, 143, 164

Plastic pipe and fittings — 41

Power take-off drives — 4, 12, 51, 109, 114, 122, 144, 145, 158, 178, 180, 183, 184, 191, 192

Processing equipment, fruit and vegetable:
- Graders — 99, 147
- Washers and waxers — 99, 147
- Packaging equipment — 99, 147

Pumps — 9, 11, 27, 68, 84, 92, 95, 102, 104, 145, 172

Pumps, gear — 99

Scales — 36, 68

Scoops — 35

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Stack movers — 65

Stackers — 13, 22, 36, 65, 68, 114, 142

Steering, power—26, 49, 149, 176, 179, 192

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Trucks (hand, platform and 2-wheel) — 13, 22, 33, 36, 44, 56, 61, 142, 145, 168

Trucks, industrial (fork lift trucks) **and attachments** — 5, 13, 22, 71, 73, 78, 98, 101, 129, 142, 172

Universal joints—68, 110, 122, 145, 146, 184

Unloaders:
- Silo — 21, 66, 176
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Wagons — 31, 52, 59, 69, 72, 75, 81, 89, 103, 114, 124, 125, 126, 145, 151

Wagon boxes, racks, hardware — 12, 34, 52, 63, 68, 69, 72, 75, 81, 114, 124, 125, 132, 145

Wagon box hoists — 32, 52, 68, 75, 81, 98, 114

Waterers — 82, 113

Wheels and tires — 13, 56, 59, 64, 68, 74

Winches — 12, 32, 98, 157, 191

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(See page 579)

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66. The Farmway Co., 1034 Depot St., Manawa, Wis.
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70. Fuller Co., Catasauqua, Pa.
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80. Hewitt-Robins, Stamford, Conn.
81. Hotchkiss Steel Products Co., Bradford, Ill.
82. H. D. Hudson Mfg. Co., 589 E. Illinois St., Chicago, Ill.
83. Hydra-Flex, Inc., Claremont, Minn.
84. Hydro-Speed Equipment Co., 2147 E. 37th St., Los Angeles 58, Calif.
85. Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.
86. The Jeffrey Mfg. Co., North 4th St., Columbus 16, Ohio
87. Johnson Farm Machinery Co., 907 3rd St., Davis, Calif.
88. G. A. Kelly Plow Co., 101 S. Center St., Longview, Tex.
89. Kewanee Machinery & Conveyor Co., Kewanee, Ill.
90. **Kohler Co.**, Kohler, Wis.
91. Kools Brothers Inc., Appleton, Wis.
92. O. W. Kromer Co., 1120 Emerson Ave. No., Minneapolis 11, Minn.
93. **A. Lakin and Sons, Inc.**, 2044 N. Dominick St., Chicago 14, Ill.
94. Lantz Mfg. Co., Inc., 902 Calumet Ave., Valparaiso, Ind.
95. **Lincoln Engineering Co.**, 4010 Goodfellow Blvd., St. Louis 20, Mo.
96. **Link-Belt Co.**, Dept. AEMH-58, Prudential Plaza, Chicago 1, Ill.
97. Link-Belt Speeder Corp., 1201 Sixth St., S.W., Cedar Rapids, Iowa
98. Little Giant Products, Inc., 1530-50 N.E. Adams St., Peoria, Ill.
99. Lobee Pump & Machinery Co., State St., Gasport, N. Y.
100. **The Locke Steel Chain Co.**, P.O. Box 189, Huntington, Ind.
101. Love Mfg. Co., Eau Claire, Mich.
102. A. Y. McDonald Mfg. Co., 12th and Pine St., Dubuque, Ia.
103. The A. E. MacKissic Co., Parker Ford, Pa.
104. Marlow Pumps, Div. of Bell & Gossett Co., P.O. Box 200, Midland Park, N. J.
105. **Marvin Landplane Co.**, P.O. Box 209, Woodland, Calif.
106. Mason City Brick & Tile Co., 200 Brick & Tile Bldg., Mason City, Ia.
107. Master-Bilt Refrigeration Mfg. Co., 4209 Folsom, St. Louis 10, Mo.
108. May-Fran Engineering Inc., 1710 Clarkstone Rd., Cleveland 12, Ohio
109. Mayrath Machinery Co., Inc., East Trail St., Dodge City, Kans.
110. Mechanics Universal Joint Div., Borg-Warner Corp., 2020 Harrison Ave., Rockford, Ill.
111. Melos Manufacturing Co., 2010 Hubbell, Des Moines, Ia.
112. Miller Mfg. Co., P.O. Box 1490, Modesto, Calif.
113. Milwaukee Tool & Equipment Co., 2773 S. 29th St., Milwaukee 46, Wis.
114. Minneapolis Freeman Mfg. Co., 5610 W. 36th St., Minneapolis 16, Minn.
115. Miskin Scraper Works, Inc., Ucon, Idaho
116. Monarch Road Machinery Co., 1331 Michigan St., N.E., Grand Rapids 3, Mich.
117. Moore's Irrigation Co., 703 N. 11th St., Corvallis, Ore.
118. Morse Chain Co., S. Aurora St., Ithaca, N. Y.
119. Munson Mill Machinery Co., 210 Seward Ave., Utica 1, N. Y.
120. **National Rain Bird Sales & Engineering Corp.**, 627 N. San Gabriel Ave., Azusa, Calif., and 609 W. Lake St., Peoria, Ill.
121. **National Seal Div.**, Federal-Mogul-Bower Bearings, Inc., Redwood City, Calif.
122. **Neapco Products Inc.**, Pottstown, Pa.
123. **New Departure**, Div. General Motors Corp., Bristol, Conn.
124. **New Holland Machine Co.**, New Holland, Pa.
125. New Idea Farm Equipment Co., Coldwater, Ohio
126. North American Mfg. Co., 3100 Correctionville Rd., Sioux City 5, Iowa
127. Nuway Gate Co., Box 815, Grand Island, Nebr.
128. **The Ohio Rubber Co.**, Div. of the Eagle-Picher Co., 130 Ben Hur Ave., Willoughby, Ohio
129. The Oliver Corp., 400 W. Madison St., Chicago 6, Ill.
130. Olson Mfg. Co., 620 S. Broadway, Albert Lea, Minn.
131. Oswalt Industries, Inc., Box 274, Garden City, Kans.
132. Papec Machine Co., Shortsville, New York

(Continued on page 596)

Recent Publications on Feed Handling (1946-1958)

IN the interest of compiling a bibliography of recent publications on feed handling, the ASAE Committee on Feed Handling contacted all known agencies and organizations interested in the subject.

Listings are grouped under the following headings:

Feed handling—general
Grains and concentrates handling
Hay handling
Silage handling

It will be noted that many of the items listed under "General" have significance in the areas of specific classifications of feed materials. Likewise there is an overlapping of applicable information between "Hay" and "Silage".

Key to publication type:

(TB) — Technical Bulletin
(TP) — Technical Paper
(EC) — Extension Circular
(PA) — Popular Article
(UR) — Unpublished Report

Feed Handling — General

Albaugh, Reuben, Kelley, G. F. and Belton, H. L. (EC) Beef handling and feeding equipment. Calif. AES Cir. 414, May 1952.

Algeo, J. W. (EC) Mechanizing cattle feeding and lessening hand labor. Wash. State Col. Dept. Animal Husbandry Stockman's Handbook p. 196-197, December 1955.

Altman, Landy E. (EC) Automatic livestock waterers. USDA Leaf. 395, November 1955.

Beresford, H. (EC) Idaho labor-saving ideas. Univ. of Idaho Ext. Bul. 158, 1946.

Brookfield, M. B. (UR) Forage elevator. 1950 Prog. Rep. to N. Y. Farm Elect. Council, N. Y. State College of Agr., March 1951.

Brownson, L. (TP) Field report on automatic feeding. Nat'l. Assoc. Silo Mfrs., Proc. 43, p. 22-39, 1955.

Bruhn, H. D. (TP) Pelleting grain and hay mixtures. AGRICULTURAL ENGINEERING, Vol. 36, No. 5, p. 330-331, May 1955.

Bruhn, H. D. (UR) An all-purpose crop conditioning structure. Univ. of Wis., 1957.

Butlien, Sheldon, and McGurk, J. L. (EC) A study of the cost and operation of mechanical barn cleaners. Cornell Univ. Ag. Eco. 826. Mimeo., July 1952.

Byers, George B. (TB) Effect of work methods and building designs on building costs and labor efficiency for dairy chores. Ken. AES Bul. 589, June 1952.

Cargill, B. F., and Ralston, N. P. (TP) Progress report of loose housing for dairy cattle in steel building. *Mich. AES Quarterly Bul.*, Vol. 38, No. 1, August 1955.

Chambers, C. R. (EC) Mechanical livestock feeding. Wash. State Col. Dept. Animal Husbandry Stockmen's Handbook, p. 17-18, December 1955.

Curley, R. G. and Dobie, J. B. (EC) Feed handling and storage, Agr. Ext. Ser. Univ. of Calif., Davis. 1957.

DeForest, S. S. (UR) Development of a high speed drag-type elevator for chopped forages. MS Thesis. Iowa State College, 1957.

DeForest, S. S. (EC) Materials handling. Advertising Dept., *Successful Farming*. 1955.

Acknowledgment: The ASAE Committee on Feed Handling—R. W. Kleis (Chairman), I. P. Blauser, L. A. Brooks, W. G. Buchinger, M. W. Forth, K. A. Harkness, B. P. Hess, B. A. McKenzie, M. Nabben, J. H. Oliver, C. K. Otis, R. M. Peart, and R. P. Prince—wishes to express appreciation for fine cooperation received from those agencies and organizations contributing to this report.

Dixon, J. and Martin J. W. (EC) Feed handling equipment. Univ. of Idaho, PNW, No. 12, 1956.

Dobie, John B. (TP) Mechanical feeding of livestock. AGRICULTURAL ENGINEERING, Vol. 36, No. 7, p. 456, July 1955.

Dobie, John B. (EC) Planning a liquid manure system. Univ. of Calif., Davis, 1954.

Dobie, J. B. and Kleist, L. C. (PA) Heating poultry drinking water, Univ. of Calif., Davis, 1954.

Dudley, A. (PA) Mobile pelleting — new concept in feed production? *Farm Mangt.*, Vol. 6, No. 8, p. 26-28, August 1957.

Duffee, F. W. (PA) Efficient forage handling. *Guernsey Breeders' Jour.* (Peterborough) Vol. 100, No. 1, p. 21-23, 30, July 1957.

Duffee, F. W. and Brooks, L. A. (TB) Feed carts make light work of heavy chores. Univ. of Wis. AES Spec. Bul. 2, June 1952.

Garnsey, E. E. (PA) Automation in the feed lot. *Cattleman*, Vol. 44, No. 5, p. 32-33, 52, 54-56, 58, October 1957.

Geiser, Stan. (PA) Handling water. *Successful Farming* — Materials handling-newest farm science, Part V, 1955.

Goss, J. R. and Jones, L. G. (EC) Problems in pneumatic lifts. Univ. of Calif., Agr. Eng. Dept., Davis, 1956.

Gowder, M. T. (EC) Farm machinery vs. hand labor. Mimeo. Univ. of Tenn., December 1950.

Greig, Eugene S. (UR) Some mechanical devices for handling livestock feeds. Thesis in Agr. Engr., Univ. of Idaho, May 1954.

Guffey, J. E. (UR) Bedding requirements for dairy cows in loose and conventional housing. MS Thesis, Penn State Univ., 1957.

Hall, Carl W. (TP) Agricultural processing, past, present, and future. AGRICULTURAL ENGINEERING, Vol 38, No. 6, p. 436, June 1957.

Hanson, Dick. (PA) Materials you buy. *Successful Farming* — Materials handling-newest farm science, Part VI, 1955.

Hecht, Reuben W. (TB) Labor used for livestock. ARS Statistical Bul. 161, May 1955.

Hecht, Reuben W. and Barton, Glenn T. (TB) Gains in productivity of farm labor. USDA Tech. Bul. 1020, December 1950.

Hodges, L. H. (TP) The design of a general-purpose farm wagon rack for mechanical unloading. AGRICULTURAL ENGINEERING, Vol. 30, No. 3, p. 124, March 1949.

Hodgson, R. E. (TP) What engineers should know about feeds for dairy cattle. Paper, ASAE, Chicago, Ill., December 1953.

Hoglund, C. R. (TB) Economics in producing and feeding roughage and grain to dairy cows. Mich. State Univ. Ag. Eco. 620, June 1955.

Hudson. W. G. (TP) Evaluating materials handling layouts. *Chem. Eng.*, Vol. 54, No. 8, p. 110-112, August 1947.

Keepers, W. F. (PA) Farm materials handling: special applications: mechanical feeding. *Impl. & Tractor*, Vol. 71, No. 18, p. 30-31, September 7, 1957.

Keepers, W. F. (PA) Replace baskets and shovels with mechanical feeders. *Hoard's Dairyman*, Vol. 102, No. 2, p. 68, January 25, 1957.

Kelly, C. F., Bond T. E. and Ittner, N. R. (TP) Engineering design of a livestock physical plant. AGRICULTURAL ENGINEERING, Vol. 34, No. 9, p. 601-7, September 1953.

Kelly, C. F. and Dobie, J. B. (PA) Build a fence-line feed bunk. *Hoard's Dairyman*, 1957.

Klein, G. T. (EC) Saving labor on poultry farms. Ext. Ser., Univ. of Rhode Island, Kingston, 1953.

Kleis, R. W. (EC) Reducing labor in handling feed. Agr. Engr. Dept., Univ. of Ill., RE-15, 1955.

Kleis, R. W. (UR) An analysis of systems and equipment for handling materials on Michigan livestock farms, Unpublished Ph.D. Thesis, Mich. State Univ., 1957.

Kleis, R. W. and Wiant, D. E. (UR) Materials handling — methods and labor requirements. Mich. State Univ., 1957.

Kleis, R. W. and Wiant, D. E. (TB) Materials handling on livestock farms, No. 40-46, Mich. State Univ., 1958.

Kleis, R. W. (EC) Planning a materials handling system for a livestock farm. Univ. of Mass., FE-1, 1958.

Kleis, R. W. (EC) Materials handling labor on dairy farms, Univ. of Mass., FE-2, 1958.

Knight, W. H. and Dixon, J. E. (EC) Electric elevators and conveyors find many farm uses, Agr. Engr., Univ. of Idaho, FE Leaflet 30, 1955.

Knight, W. H. and Craig, E. S. (EC) Tramp iron in livestock feeds. Agr. Engr., Univ. of Idaho, FE Leaflet 28, 1954.

Knight, W. H. (EC) Labor saving ideas. Univ. of Idaho, Agric. Engr. FE Leaflet 15, 1951.

Lamp, B. J., Jr. (PA) Safety problems with farm elevators. News in Engineering, Eng. Exp. Sta., Ohio State Univ., February 1957.

Lamp, B. J. Jr. and Stuckey, W. E. (EC) Live longer with portable farm elevators. Bul. 367, Ohio AES.

Larson, L. W. (PA) The farmstead—next frontier for mechanization. *Impl. & Tractor*, Vol. 73, No. 1, p. 62-64, January 11, 1958.

Longhouse, A. D., *et. al.* (PA) Liquid manure is valuable. Science serves your farm. Quarterly Rep., W. Va. AES, 1953.

Millier, W. F. (PA) Reducing labor needs in dairy barns. Minn. Farm & Home Science, Vol. VIII, No. 2, 1951.

Millier, W. F. (TP) Batch weighing and processing of dairy ration, AGRICULTURAL ENGINEERING, Vol. 32, No. 10, 1951.

Mowery, A. S., Clyde, A. W. and Walton, H. V. (UR) A vertical elevator for handling chopped forage. Penn State Univ., February 1952.

Mowery, A. S., Clyde, A. W. and Walton, H. V. (PA) Vertical cuts power needs. Science for the farmer. Penn State Univ. AES, March 1952.

Olver, E. F., Mowery, A. S. and Clyde, A. W. (UR) A home built wagon box. Penn State Univ. AES Prog. Rep. 45, March 1951.

Parks, R. R. (TP) Mechanical feeding with worksavers. AGRICULTURAL ENGINEERING, Vol. 32, No. 10, p. 554, October 1951.

Perry, R. L. (TP) Tank collection of milk from farms, AGRICULTURAL ENGINEERING, Vol. 32, No. 9, 1951.

Peterson, W. R. (TP) Development of mechanical equipment for unloading chopped forage. AGRICULTURAL ENGINEERING, Vol. 30, No. 4, p. 188, April 1949.

Phagen, C. V., *et. al.* (EC) Cattle feeders and equipment. Okla. Ext. Ser. Cir. 540, 1956.

Prince, R. P. (PA) Automatic feed processing on the farm. Science for the farmer. Penn State Univ. AES, p. 6, Fall 1956.

Raney, J. P. (UR) A preliminary investigation of the effect of blade shape on forage blower performance. Unpub. MS Thesis, Purdue Univ., 1957.

Rambo, E. K. (EC) Labor saving equipment and devices. Col. of Agr., Univ. of Ark. Ext. Plan 15, June 1947. *(Continued on page 598)*

Current Research Activities in Feed Handling in the United States and Canada

The ASAE Committee on Feed Handling — R. W. Kleis (Chairman), I. P. Blauser, L. A. Brooks, W. G. Buchinger, M. W. Forth, K. A. Harkness, B. P. Hess, B. A. McKenzie, M. Nabben, J. H. Oliver, C. K. Otis, R. M. Peart and R. P. Prince, has recently conducted a survey of various agencies and organizations to determine the amount and nature of activity in feed handling research being conducted in the United States and Canada.

Survey results indicate that many research projects are extremely broad in title and objectives and that a great amount of overlapping and perhaps duplication of research effort exists. The committee feels that this need not be disturbing if the individuals involved are aware of other work similar to theirs and of the procedures and results of these other programs. It also feels that perhaps this compilation will facilitate coordination.

The committee points out that this compilation cannot be regarded as complete, since most of the entries reported represent public service organization activities. It is felt that much excellent research and development work has not been reported since a general reluctance exists by industry to release information about this type of work.

The listings, as reported, are grouped under the following headings:

Feed Handling — General

Grains and Concentrates Handling

Hay Handling

Silage Handling

FEED HANDLING — GENERAL

Alabama—Alabama Polytechnic Institute—Feed processing and storage costs on dairy farms

December 1956 to December 1958

(a) Operation of an experimental feed processing plant to determine practices and costs. *(b)* Survey to determine methods in use by Alabama dairy farmers.

C. A. Rollo in charge.

California — University of — Materials handling

1956 to 1958 or 1959

Preparation of material on materials handling and mechanical feeding of livestock for publication as a circular. Completed research provides basis for part of publication.

John B. Dobie in charge.

Clemson — See South Carolina

Cornell — See New York

Idaho — University of — The design and evaluation of farm mechanization systems under Idaho conditions

March 17, 1955 to 1958

To survey an inventory the present status of farm mechanization in Idaho.

W. L. Moden in charge.

Idaho — University of — Farm electrification

1956 to 1959

Mechanization of feed handling.

D. W. Works in charge.

Illinois — University of — Development of a high-capacity forage elevator

January 1955 to January 1959

Development of a vertical elevator with forked flights has the objective of 50 tons per hour of corn silage and 30 tons per hour of grass silage. Several laboratory models and one 40 ft test model have been constructed and tested. A 5 hp electric motor is expected to power the unit.

F. L. Herum in charge.

Iowa — Cedar Falls — (Clay Equipment Corp.) — Barn cleaner development

Developing a single gutter barn cleaner (as differentiated from present two gutter cleaner). Redesign of silo unloader to make it suitable for either a single or double auger machine.

Roger Clay, president, in charge.

Kentucky — University of — Materials handling — general

Summer 58 to indefinite

Questions of local nature and others related to mechanical feeding of livestock.

Blaine F. Parker in charge.

Michigan — State University — Materials handling on the farm

July 1, 1956 to July 1, 1958

To study methods and procedures of handling farm materials on 330 Michigan farms.

D. E. Wiant in charge.

Minnesota — University of — Structure and related equipment for efficient operation of the dairy enterprise

Revised July 1, 1957 to 1962

This study is aimed at attempting to find ways of improving the efficiency of man labor in the profitable operation of dairy enterprises. It deals with arrangements, buildings and mechanical equipment in relation to economy of labor, materials, and land. Examples are *(a)* field handling from storage to the milking stall for loose housing systems, *(b)* feed processing system for reduction of labor in preparation of the ration, *(c)* development of a mechanically unloaded flat-bottomed ground-feed storage bin.

C. K. Otis in charge.

Minnesota—Agricultural Experiment Station—Reduction in labor in farmstead operations for the dairy enterprise

Spring 1957 to 1962

Studies of 20 farms in each of three locations—California, Minnesota and Maryland —are aimed at determining labor and time requirements for various chores. Mechanical methods of handling routine, laborious and time-consuming chores are being studied simultaneously and as problems are uncovered by the time studies.

R. Larson in charge.

Missouri — University of — Forage harvesting, handling and feeding

1953 to 1960

Effort to completely mechanize the forage enterprise from cutting to feeding

D. B. Brooker in charge.

Nebraska — University of — Rate of domestic water use on the farm as it affects the design of farm water systems

March 17, 1955 to 3 to 5-years from starting date

A determination of the rates of use and pressure requirements of water systems on farms. Data will serve as a basis for the design of adequate farm water systems.

F. D. Yung in charge.

New York—Cornell University—R & M 35 contributing to regional project NE-13

July 1, 1954 to June 30, 1958

The development of materials handling methods and equipment for reducing labor in caring for livestock; including reference to harvesting, processing, storing and feeding.

W. F. Millier in charge.

North Carolina—State College—Forage drying and preservation

Fundamental and applied research in equipment and methods for preservation of forage crops.

J. W. Weaver, Jr. in charge.

North Dakota — State College — Mechanization handling of silage and grain to feed bunks in open feed lots

Developed lazy susan feeder and silage throwing units. Now working on automatic feed mixing and grinding for dairy cows.

R. L. Witz in charge.

Oregon—Portland—Feeder wagon and manure spreader combination

In process 2 years to indefinite date

Feed green chopped feed, chopped hay, silage, mixed feed.

Percy F. Freeman in charge.

Pennsylvania—State University—Equipment for efficient poultry production

1958 to 1961

To develop equipment for poultry management in areas where labor efficiency may be improved.

To study designs and arrangements of feeding, watering and roosting equipment for reduced feed wastage, water spillage and feather soilage, and for efficient space and labor utilization.

H. D. Bartlett in charge.

Pennsylvania — State University — Handling chopped forage

1950 to 1959

To evaluate present methods and devise new methods for handling chopped hay and corn from the field to the mow or silo.

W. L. Kjelgaard in charge.

Pennsylvania—State University—An economic and engineering appraisal of mechanical dairy barn gutter cleaners

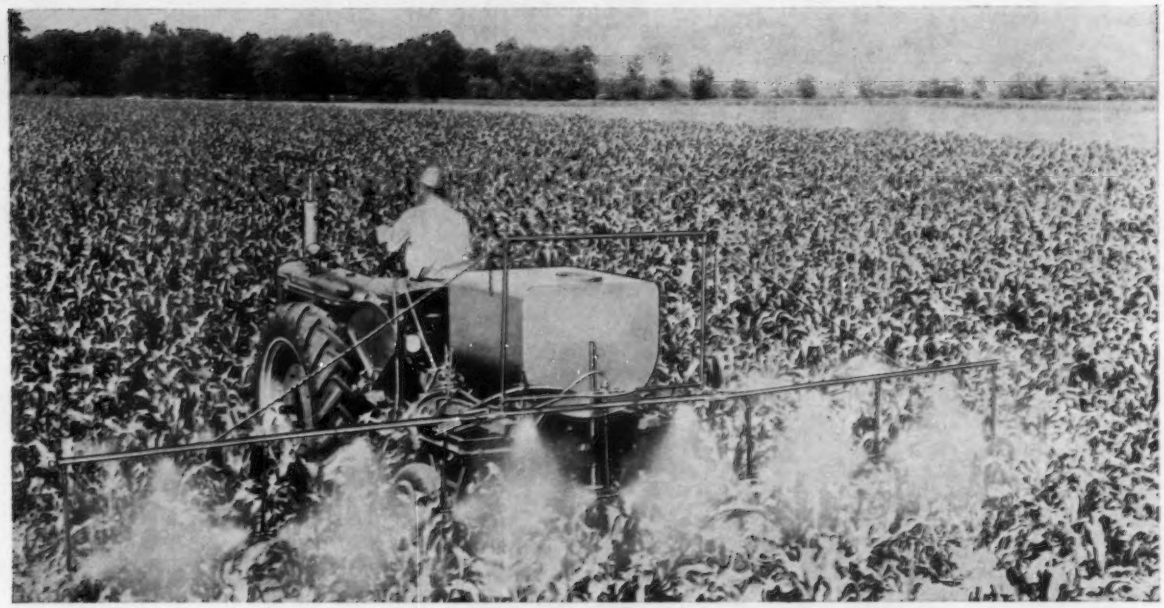
1956 to 1959

To evaluate the effect of bedding material on gutter cleaner operation.

To investigate the physical forces imposed upon different types of gutter cleaners.

M. E. Schroeder in charge.

(Continued on page 584)



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. . . Research Activities

(Continued from page 582)

Pennsylvania—State University—Methods, materials and equipment involved in the dairy operation

1956 to 1959

To measure the relative efficiency of performing routine chores under systems of loose and conventional housing.

M. E. Schroeder in charge.

South Carolina—Clemson Agricultural College—Design of automatic feed handling and processing installations

1957 to indefinite

To design automatic feed processing and handling installations. These designs will emphasize the efficient use of labor through the utilization of modern and automatic equipment and the use of equipment which will either improve or maintain quality of the product being processed.

To utilize the above designs in preparing plans for distribution.

E. B. Rogers, Jr. in charge.

USDA — ARS, Agricultural Engineering Research Division—Reducing time and labor in caring for dairy animals through improved layout of building and yards, and the selection and adaptation of equipment

November 1956 to November 1959

Through an engineering approach to determine the elements involved in labor saving on the farmstead and to develop therefrom *(a)* time standards for specific jobs; and *(b)* principles that may be applied in planning the farmstead and in design of buildings.

John W. Rockey in charge.

Vermont—University of—Mechanical handling and metering of forage for dairy cows in stanchions and in loose housing

Approximately 1948 to indefinite

Removing from storage, metering them and conveying them to livestock.

E. C. Schneider in charge.

West Virginia — University, Agricutural — The mechanization of forage crop harvesting, processing, storing and feeding, NE-13

July 1, 1954 to 1960

To determine the mechanical requirements and develop methods and equipment for the production of high quality forage with special reference to the operation of: harvesting, processing, storing, and feeding.

A. D. Longhouse in charge.

Wisconsin—University of—University of Wisconsin electric research farm food storing and processing

1953 to indefinite

Reduction of chore time on Wisconsin farms. Assembly of equipment to study the economics of complete mechanization of processing and handling farm grown feeds from storage to the cow.

L. A. Brooks in charge.

Wisconsin — University of — Electric research farm

1945 to indefinite

Application of labor saving equipment around the dairy farmstead including chopped hay conveyor system, manure handling, and grain grinding and handling.

L. A. Brooks in charge.

GRAIN AND CONCENTRATE HANDLING

Arkansas—University of—Automatic feeding of ground feeds to dairy cattle

1958 to 1960

Evaluation of the performance of automatic feeding systems as compared to conventional hand feeding. Investigation of the performance of various feed metering devices for metering ground feeds.

Edwin J. Matthews in charge.

California—University of—Forage seed harvesting and processing

1953 to 1962

Objectives pertaining to feed handling—*(a)* conduct field and laboratory studies of the pneumatic conveying process to determine the basic equations involved and factors affecting mechanical damage to seed, *(b)* determine and measure the physical characteristics of seeds that determine pneumatic conveying characteristics.

John R. Goss in charge.

Colorado—State University—Pneumatic separation for grains

January 1, 1958 to indefinite

Development of performance data on an air separator manufactured in Colorado and fundamental studies on the mechanics of such separation—contract research.

Norman A. Evans in charge.

Colorado—State University—Pneumatic conveyance of grains

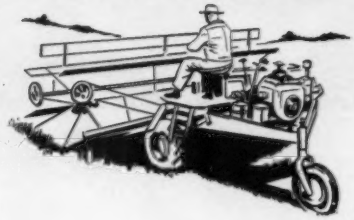
July 1957 to indefinite

Fundamental fluid mechanics study of mechanics of particle transport in air.

Norman A. Evans in charge.

(Continued on page 586)

ON THE BOARD or ON THE MACHINE...



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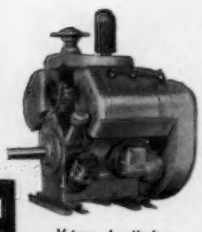

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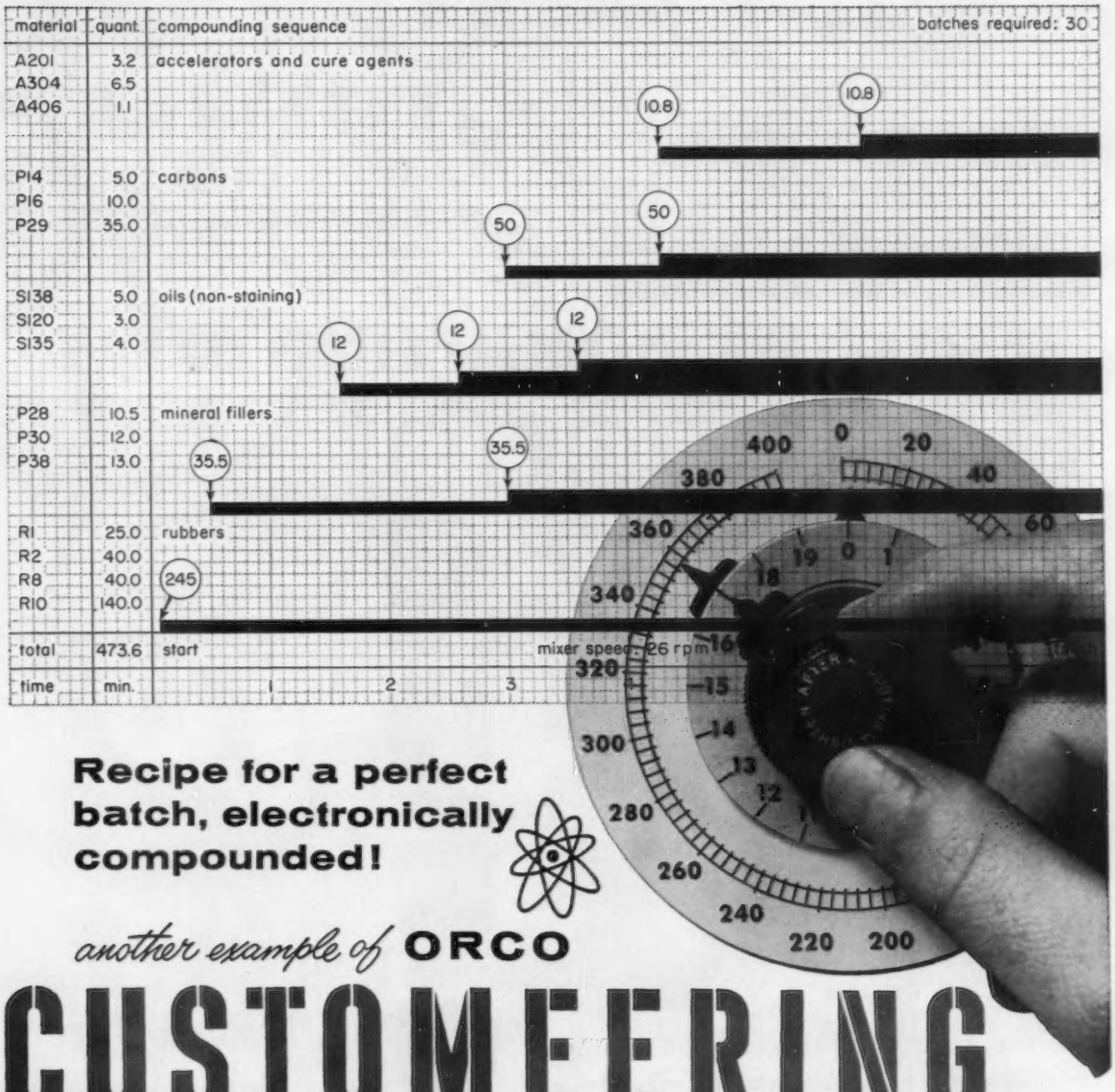

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Here is just another reason why Ohio Rubber is widely recognized as an outstanding producer of "customeered" parts from rubber, synthetic rubber, silicone rubber, polyurethane and flexible vinyl—whether molded, extruded or bonded to metal.

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(For more facts circle No. 76 on reply card)

. . . Research Activities

(Continued from page 584)

Georgia — University of — Drying and storing grain and seed in Georgia and the Southeast

Determining: *(a)* requirements for drying commercially important grains and seeds with heated and unheated air, *(b)* basic relationships such as equilibrium moisture contents, heat of vaporization, and drying rates, *(c)* solution of problems involved in drying with unheated air in divergent flow, *(d)* feasibility of using solar radiation as a source of supplemental heat for drying.

J. W. Simons in charge.

Illinois—University of—Metering high moisture corn

June 1958 to June 1959

Check accuracy and dependability of various types of feed meters when used with high moisture corn. (18 to 30 percent wet basis).

Robert M. Peart in charge.

Illinois—University of—Bin unloader for a flat bottom bin

September 1956 to March 1958

An auger type unloader has been developed that will automatically unload a flat bottom round bin completely and automatically. Two separate motors power the two augers. One auger removes feed from the center of the bin and the other auger sweeps around the bin when necessary, moving material to the center.

H. B. Puckett in charge.

Illinois—University of—Automatic hog fattening plant

March 1957 to indefinite

A complete housing and materials handling system is being built to handle swine from weaning age to market size with no manual labor and little attention. The feed handling system includes 2 experimental self-unloading bins, a commercial automatic feed mixer grinder, an experimental high pressure pneumatic conveying system, an experimental automatic auger type hog feeder, an experimental high pressure spray boom for cleaning the manure from the droppings area, and equipment to handle the liquid manure from storage.

E. L. Hansen in charge.

Illinois — University of — High pressure pneumatic conveying of feed

1956 to March 1960

(a) Theoretical and experimental evaluation of the relationships between pressure, length of pipe, size of pipe, feed material, feed conveying rate, and type of interior surface of the conveying pipe in the range of 5 to 45 psi, 1 and 1½-in. pipe, 50 to 200 ft of length. *(b)* Development of a lower cost feed injector to meter feed into the high pressure air line.

H. B. Puckett in charge.

Kansas—State College—Feed processing

The present research is aimed at an improved small grains metering device. The desired metering device is one that is relatively inexpensive and easily adjusted to give the desired rate of flow. The use of a burr mill in a labor saving feed grinding system is also being studied. This included experimental work to determine the ability of a burr mill to meter and grind grains individually and simultaneously.

Ralph I. Lipper in charge.

Michigan — State University — Grain storage and handling system analysis

September 1957 to September 1958

Grain storage and handling systems for livestock farms will be synthesized. Cost comparisons then will be made for different volumes of grain. Final cost will be determined in terms of handling efficiency and labor.

D. E. Wiant in charge.

Missouri—University of—Utilization of electricity on Missouri farms

1956

Project includes a sub-project on grinding, mixing and handling livestock feeds on Missouri farms. Work includes processing feeds with hammer and roller mills, power requirements, bin arrangements, etc.

Kenneth L. McFate in charge.

Missouri — Independence — Efficiency of hog self-feeders

Third Quarter 1957 to May 31, 1958

Comparison of round and rectangular feeders; economy of feed use; what capacities should be standard; methods of filling.

L. F. P. Curry in charge.

Ohio—Dayton—Feed grinder tests

To determine operating costs of newly developed feed processing unit.

C. W. Shoup in charge.

Ohio—Orient—Development of improved farm feed mixing and transporting wagon

May 1958 to November 1958

To develop, if feasible, a competatively priced feed mixing wagon capable of thorough mixing of feeds on the farm. Unit is

(Continued on page 588)

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Help Make Farm Machines Efficient and Reliable

This RM type Spring-Loaded Clutch is available in sizes from 6½" to 12". Torque capacity 80 to 480 foot pounds. Furnished with or without dampener feature and with facings for dry or in-oil operation. An efficient, LOW-COST design clutch adopted by leading manufacturers of tractors and other farm machines.

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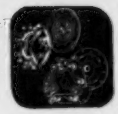

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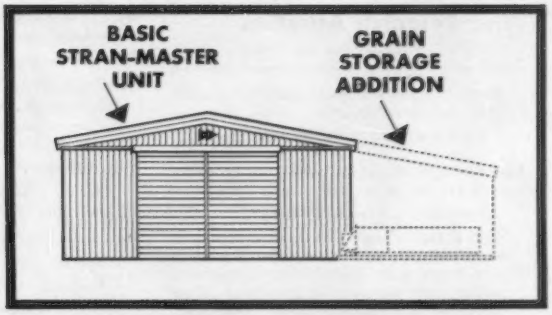

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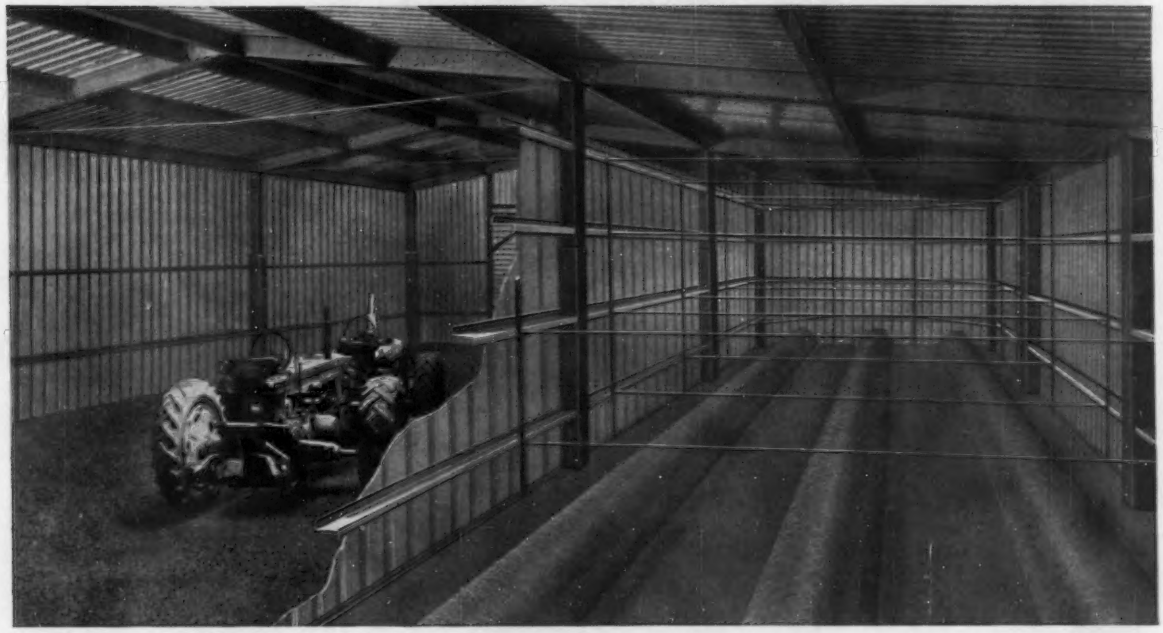

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(For more facts circle No. 97 on reply card)

. . . Research Activities

(Continued from page 586)

planned to mix also small quantities of additives such as antibiotics.

Vernon C. Belt, President, in charge.

Ontario—Agricultural College—Study of shelled corn storage in an hermetically sealed unit

September 1957 to May 1958

A fibreglass corn bin was designed to store 1000 bu of shelled corn. This unit was hermetically sealed after temperature studies were made during processing. Mold studies and nutritional studies were made during feeding to beef cattle.

J. Pos in charge.

Pennsylvania—State University—Handling and processing grain on the farm

1955 to 1959

To develop an integrated system for handling and processing grain from the initial storage to the final feeding, the system to be of moderate cost and to lend itself to step by step construction.

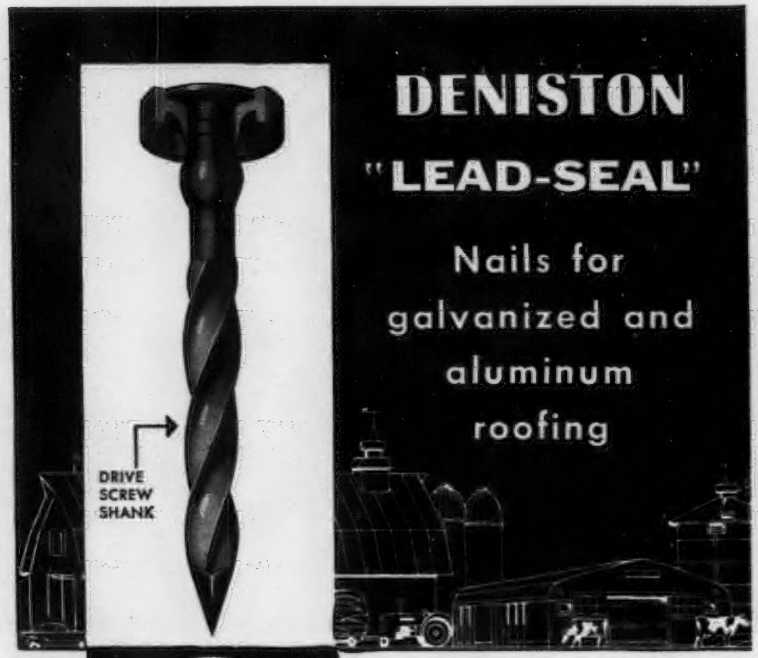
W. L. Kjelgaard in charge.

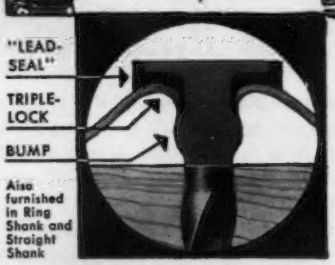
Vermont—University of—Metering dairy rations

August 1952 to 1958

Metering varying weighed amounts of ground dairy concentrates for dairy cows in the stanchion or milking parlor.

E. C. Schneider in charge.





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Vermont—University of—Bulk grain bins for dairy rations

February 1956 to indefinite

Investigation of the behaviour of ground dairy rations, with high molasses content, in bulk grain bins, and the development of a satisfactory mechanical means of preventing or overcoming the effects of bridging and caking.

E. L. Arnold in charge.

West Virginia—University Agricultural—Study of the design and operating characteristics of a grain conveyor using fluidization principles

1950 to indefinite

1 Design and build a laboratory unit of transparent lucite so as to observe conditions in the fluidizing chamber.

2 Design and build a full size unit capable of handling at least one ton of grain per hour.

(a) Test unit in the laboratory for performance characteristics.

(b) Install unit at one of the university farms to determine practicability and operation costs under actual farm conditions.

A. D. Longhouse in charge.

HAY HANDLING

Arkansas—University of—Engineering aspects of artificial drying and storage of hay

1957 to 1960

Investigations of structures, machinery methods of storage and self-feeding of hay. Presently concerned with chopped hay in a self-feeding bin and loose hay in a plastic covered field stack.

Edwin J. Matthews in charge.

California—University of—Pelleting of forage

1956 to 1960 or later

Study of criteria affecting the processing of forage into pellets and briquets, the development of new methods and equipment for farming forage into pellets, and the mechanics and economics of storing and handling pelleted forage.

John B. Dobie in charge.

Iowa—State College—Self-feeding chopped hay

1950 to 1960

Development, modification and test of upright cylindrical structures for drying and self-feeding chopped hay.

K. K. Barnes in charge.

Maine—University of—Forage handling mechanization

July 1954 to indefinite

Handling baled hay and chopped forage.

Nathan H. Rich in charge.

Maryland—University of—Pneumatic handling of chopped forage

July 1954 to 1960

The object of this project is to devise a method using air, to place partially cured chopped hay on a hay drying system.

Kenneth E. Felton in charge.

Massachusetts — University of — Mechanical removal of hay from mow

January 1, 1958 to December 30, 1960

Design and development of an automatic unit for removing hay from elevated mows.

R. W. Kleis in charge.

Michigan — State University — Power requirements for moving hay on flight conveyors

June 1957 to indefinite

Studying the power requirements to move baled hay on a flight type conveyor, a cali-

(Continued on page 590)

Let Alcoa Research help you help farmers

Alcoa's 70-man research team has been taking a long, close look at aluminum products for the farm. Their work has been showing up in the quality products Alcoa offers for farm use.

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- ☐ Alcoa Farm Gate Literature. Facts about aluminum gates.
- ☐ *Pole Barn Plans Catalog.* Describes Alcoa plans for nine pole buildings.

*Films may be borrowed for public showings. Specify dates wanted.

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(For more facts circle No. 80 on reply card)

. . . Research Activities

(Continued from page 588)

brated electric motor is used to supply power, the results are compared with calculated values; a centrifugal clutch was investigated and friction of hay on wood.

D. E. Wiant in charge.

Nebraska—University of—Factors affecting the drying rate and compaction characteristics of alfalfa hay

February 1958 to 1963

An investigation of the vapor pressure characteristics of alfalfa hay under various temperatures, moisture contents and conditioning treatments. Also a study of the compaction characteristics.

K. Von Bargen in charge.

Ohio — State University and the Ohio Farm Electrification Council—Development of a method for placing baled hay and straw in barn storage

June 1957 to June 1958

Consisted of development of the track hay car method of conveying bales in storage. The conventional system was modified by the use of a remote controlled hay hoist and a specially designed trip car to permit lowering and placing fork loads of bales in the mow.

Roger W. Asmus in charge.

Tennessee—University of—Structures and mechanical equipment for storing, drying and handling hay

1947 to indefinite

To determine some optimum relationships of drying factors affecting the efficient use of heat, factors affecting the color loss of hay in storage and the adaptation of elevators, storage units and hay moving devices especially as applied to round storages. It is an attempt to provide an efficient, all mechanized hay drying and storage unit.

H. A. Arnold in charge.

Vermont—University of—Automatic hay feeding in manger

1955 to indefinite

Feeding of hay from mow to manger by use of conveyor mechanism.

E. C. Schneider in charge.

SILAGE HANDLING

British Columbia — University of — Leaching losses from bunker silos

July 1958 to Fall 1959

Measurements are being taken of liquid draining from an uncovered bunker silo. Proximate analysis of liquid and silage will be done.

E. Watson in charge.

Illinois—University of—Use of a short vertical auger elevator in a silo unloader

June 1956 to June 1958

Development of a more efficient system for moving silage from the center of the top surface to the silage door is the main objective. A short vertical auger, 12 in. in diameter, in connection with a horizontal auger should be more efficient than a blower-thrower. Lab tests on the vertical auger are completed and a complete unloader using this system is being designed for testing in a silo.

Robert M. Peart in charge.

Kansas—State College—Handling and storage of silage

1954 to 1959

The overall objectives of the project are to determine the most satisfactory methods of handling, storing, and feeding silage. Methods of reducing the spoilage losses in horizontal silos by determining best methods of placing, leveling and packing silage in silo. The effect different types of covering have on reducing spoilage is being investigated.

Mechanical silo unloaders are being studied for output capacity, power requirements, and to evaluate present unloading installations.

Martin Decker in charge.

Maine—University of—USDA forage mechanization, NE-13

1955 to indefinite

Design of system for uniform unloading of wagon into conveyor or elevator.

Nathan Rich in charge.

Massachusetts—University of—Methods of making 45-50 percent moisture content silage

January 1, 1958 to December 31, 1960

Investigation of factors and characteristics of various materials which might be used to completely seal conventional silos.

R. W. Kleis in charge.

Minnesota—University of—Labor saving methods in handling and feeding silage and silo crops to dairy cattle in outside feed lots

February 1954 to June 30, 1959

Investigation of methods of handling silage and green chopped feed in outside feed lots for dairy cattle in loose housing systems. Includes handling of silage from silo to feed bunk and green chop from wagon to feed bunk.

C. K. Otis in charge.

(Continued on page 592)

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- Natural Air Drying Fans
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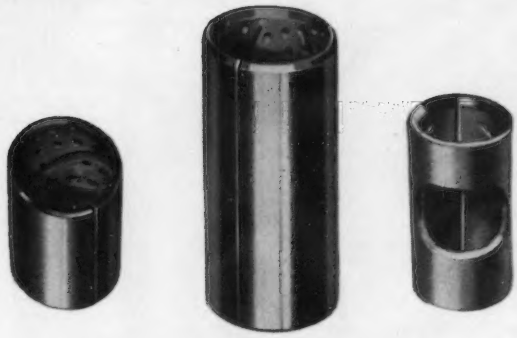

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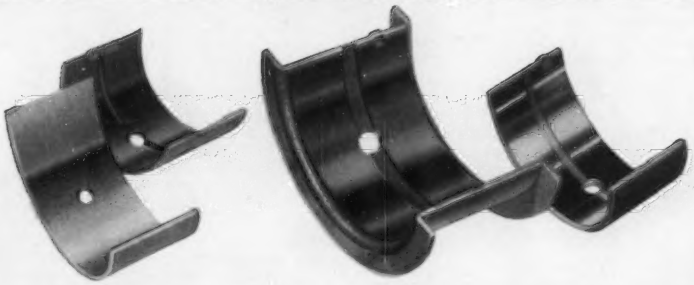

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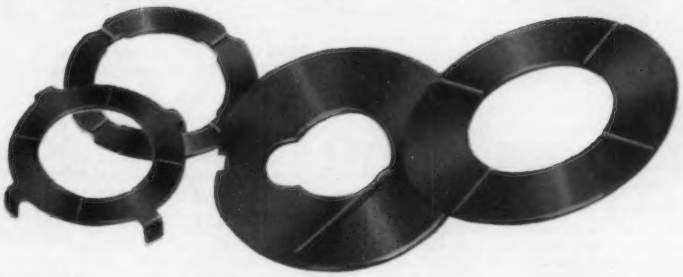

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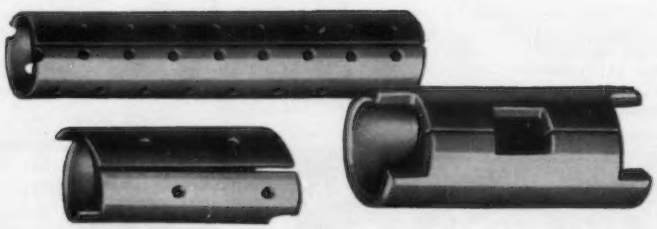

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. . . Research Activities

(Continued from page 590)

Minnesota—St. Paul 13—Silo unloaders and automatic feed bunks

1946 to indefinite

Develop, manufacture, and sell a good workable silo unloader and powered feed (silage) bunk—our feed bunk rotates around the silo—the combination should be automatic.

F. O. Rowell in charge.

Mississippi — State College — Mechanized harvesting and feeding of silage

July 1, 1956 to 1960

Studies of structures for storage and equipment for harvesting and feeding silage.

Thomas N. Jones in charge.

Ohio — State University — Silo unloaders on Ohio farms

Study of energy requirements in silage handling on Ohio farms.

Roger Asmus in charge.

Ontario—Agricultural College—Design of a fibreglas reinforced plastic silo

June 1957 to May 1958

Design, construct and investigate the results of storing silage in a 10-ft diameter, 30-ft high fibreglas-reinforced plastic silo.

F. H. Theakston in charge.

Oregon — State College — Developing low cost methods of harvesting, ensiling, and feeding grain silage

1960

Investigation includes "long" silage, baled silage, methods of piling bales, and feeding. Cheap plastic covers are also being studied.

Myron Cropsey in charge.

USDA — ARS, Agricultural Engineering Research Division — Development of improved equipment and structures for making, storing and feeding silage

October 1955 to October 1960

To study the requirements for horizontal silos, methods of making, storing and feeding silage from them and the comparative cost and efficiency of horizontal and upright silos.

J. Robert McCalmont in charge.

Wisconsin—Kaukauna—Around-the-silo feeding

Summer of 1956 to soon

Building a feed bunk around the silo with concrete silo staves and filling partially with gravel and a concrete floor and having a mechanism to carry the feed around.

Eugene Haen in charge.

EVENTS CALENDAR

September 17-19—*Farm Materials Handling Conference,* Iowa State College, Ames, sponsored by American Society of Agricultural Engineers. For further details see page 378, this issue, or write ASAE, 420 Main St., St. Joseph, Mich.

September 22-24 — *7th Annual Meeting of Standards Engineers Society* at Benjamin Franklin Hotel, Philadelphia, Pa. For further details contact F. F. Van Atta, 1916 Race St., Philadelphia 3, Pa.

September 29 - October 1—*Farm Equipment Institute Convention,* Atlantic City, New Jersey. For information write FEI, 608 S. Dearborn St., Chicago 5, Ill.

September 29, 30 and October 1 — *Fifth National Watershed Congress,* Statler-Hilton Hotel, Dallas, Tex. For further information write D. A. Poole, 709 Wire Bldg., Washington, D. C.

September 29 to October 4 — *Fifth International Congress of Agricultural Engineering* to be held in Brussels, Belgium. The aim is to stimulate the science and the techniques of agricultural engineering, as well as the use of these techniques; and to coordinate scientific research and techniques in the fields related to agricultural engineering. Registration information may be obtained by writing to M. Nestor Laret, Avenue des Combattants, 69, Gembloux, Belgium.

October 5-7 — 5th Annual *National Power Use Conference,* Hotel Statler, Buffalo, N. Y. For details write Inter-Industry Farm Electric Utilization Council, Inc., P.O. Box 577, Washington 4, D.C.

October 19-22 — Annual Conference of the *Soil Conservation Society of America,* to be held in the Auditorium of Asheville, N. C. The theme is Land and Water for Tomorrow's Living. For further information contact SCSA, 838 5th Ave., Des Moines, Ia.

October 23-25 — *The National Society of Professional Engineers,* St. Francis Hotel, San Francisco, Calif. For details contact K. E. Trombley, National Society of Professional Engineers, 2029 K St. N.W., Washington 6, D.C.

December 3-5 — Eighth Annual Convention and Trade Show of the *Agricultural Ammonia Institute,* Morrison Hotel, Chicago. Write to J. F. Criswell, AAI, Claridge Hotel, Memphis Tenn., for information.

December 29-30 — Section M—Engineering portion of Annual Meeting of the *American Association for the Advancement of Science,* Hotel Statler, Washington, D.C. Program available after October 15 from Secretary, Section M, c/o E. J. C., 29 West 39th St., New York 18, N. Y.

April 5-10—*1959 Nuclear Congress,* Public Auditorium, Cleveland, Ohio, sponsored by Engineers Joint Council, 29 West 39th St., New York, N. Y.

May 29 - June 7, 1959 — *RiLa* arranged by Swedish Federation of County Agricultural Societies and billed to be the largest agricultural show to be held in Sweden since 1946. Its aim is to give presentation of Sweden's mechanized farming and high-quality livestock breeding, and also the country's agriculture as an export-import industry. Further details may be obtained from The Swedish-International Press Bureau, Brunkebergstorg 14, Stockholm, Sweden.

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USED ON: Spring Shank Cultivators
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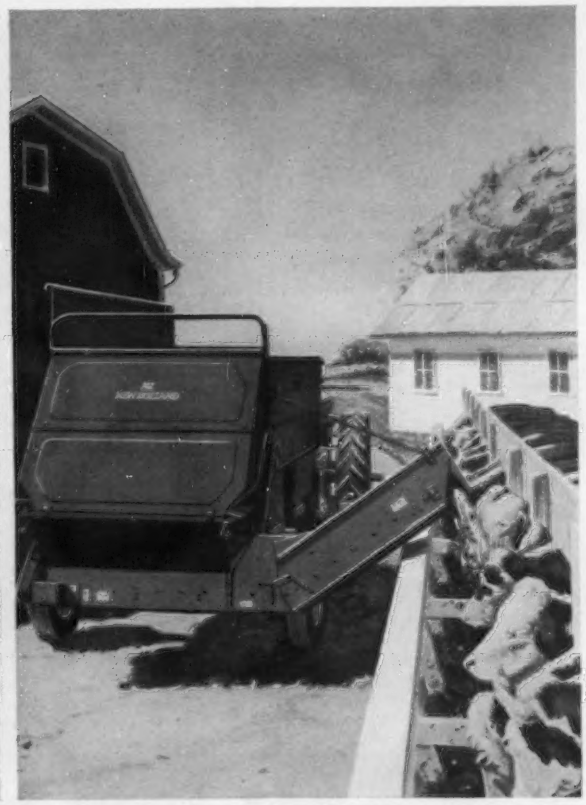
These forged cultivator stems are supplied as original equipment on a wide variety of spring shank cultivator makes and models, both of the single and double leaf types. The simple design permits fast and accurate adjustments on the lateral, vertical and horizontal planes. Since no expensive tooling is required to produce these stems, they are available as standard parts. For help with your standard or special parts, contact the agricultural forgings engineers at Pittsburgh Forgings Company.

New Holland's 335 Spreader with Forage Box teams with Model 22 Forage Blower to raise 48 tons of silage per hour.



With cross conveyor attachment, Model 335 Spreader with Forage Box becomes automatic Bunk Feeder.

Forage Box Becomes . . . Bunk Feeder

(It started as a manure spreader!)

Two simple attachments turn New Holland's 335 spreader into Forage Wagon . . . Forage Wagon into Bunk Feeder

TALK ABOUT EFFICIENT HANDLING of farm materials—this is it. New Holland's 335 Manure Spreader hauls 130 bushels each trip. Cuts trips in half. Hauls twice the load of ordinary manure spreaders. And it's versatile. The box comes off the running gear easily. Leaves the wagon free for flat beds or other racks as needed. Add the extension sides to the manure spreader and you have a forage wagon.

Mechanical loaders can't bump or catch on the arch—because there is no arch. No way for manure to jam against the beaters. What's more, the 335 hitches easily. Unloads automatically. Eliminates the need for men or forks at the blower. One convenient, easy-to-use rope controls 4 apron speeds. One man—or boy—controls everything right from the tractor seat.

Cost? It's like buying a forage wagon for less than a self-unloading box—and getting a 130-bushel manure spreader free.

And for those who prefer a two-wheel spreader, New Holland's 330 Spreader has the same capacity and versatility as the 335.

Wagon converts for daily green feeding

Add a cross conveyor to New Holland's 335 Spreader with Forage Box and you have an automatic Bunk Feeder. Feeds on the move. Lets one man feed hundreds of animals in a matter of minutes. Unloads in blowers, elevator or pit silo. Also adapts easily to become corn wagon behind picker.

These efficient material handlers are typical of New Holland's *Farm-Engineered* line of machines for grassland farming. For more information, contact New Holland Machine Company Division of Sperry Rand Corporation, New Holland, Pa.

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Pacific Coast Section

A special Soil and Water meeting of the Pacific Coast Section will be held October 9 and 10 at Riverside, Calif. Morning and afternoon sessions are scheduled for Thursday at the U.S. Salinity Laboratory. On Friday, a tour of the experimental watersheds of the San Dimas Research Center, U. S. Forest Service, will be combined with lunch and meetings on watershed management and flood control at the Tanbark Flat facility.

Michigan Section

The Michigan Section will hold its annual fall meeting October 11, at 9:30 a.m., in the agricultural engineering bldg., Michigan State University. Mr. T. A. Haller, vice-president in charge of engineering and head of the Research Development Center of the J. I. Case Co., will be the featured speaker. Papers to be presented will deal with high moisture corn storage and mechanical harvesting of cucumbers. A program for the ladies will be held concurrently with the Section meeting. A luncheon and football game, MSU vs. Pittsburgh, will conclude the day's activities.

Ohio Section

A meeting of the Ohio Section will be held October 17 and 18 at Ohio State University. The theme of the Friday afternoon session is Materials Handling and will include a talk on that subject by a national authority and case studies of farms in Ohio by extension engineers. Agricultural drainage and the accelerated highway program is the second topic to be discussed.

Ferris Owen, who has recently returned from another trip to the USSR, will be the speaker at the banquet on Friday evening.

The Saturday morning session will feature a report by manufacturers on hay conditioners, an animal scientist's report on recent developments with digestion trials, and a progress report on the new quality hay project at OSU. A football game between Indiana and Ohio State will be held in the afternoon.

Florida Section

The annual meeting of the Florida Section will be held April 16-18 at the George Washington Hotel, West Palm Beach, Fla. Program plans include a one-day field tour of the world's largest low-lift pumping station, U. S. Sugar Corporation sugar mill, commercial vegetable farms in the Everglades, and the Everglades Experiment Station. Dr. McKibben, president of ASAE, will be present and address the group. For the ladies, there will be a one-day shopping trip to Miami on the GW Yacht, at no charge.

Alabama Section

A meeting of the Alabama Section will be held October 24 and 25 at Auburn, Ala. The meeting will feature tours of the experiment station and a talk by A. W. Cooper on his trip to Russia and the World's Fair.

ASAE MEETINGS CALENDAR

October 3-4 — TENNESSEE SECTION, Memphis, Tenn.

October 9-10 — PACIFIC COAST SECTION, Riverside, Calif.

October 11 — MICHIGAN SECTION, Michigan State University, East Lansing, Mich.

October 16-17 — PENNSYLVANIA SECTION, Abraham Lincoln Hotel, Reading, Pa.

October 17-18 — OHIO SECTION, Ohio State University, Columbus, Ohio

October 22-25 — PACIFIC NORTHWEST SECTION, Oregon State College, Corvallis, Ore.

October 24 — GEORGIA SECTION, Athens, Ga.

October 24-25 — ALABAMA SECTION, Alabama Polytechnic Institute, Auburn, Ala.

October 30-31—SOUTH CAROLINA SECTION, Clemson Agricultural College, Clemson, S. C.

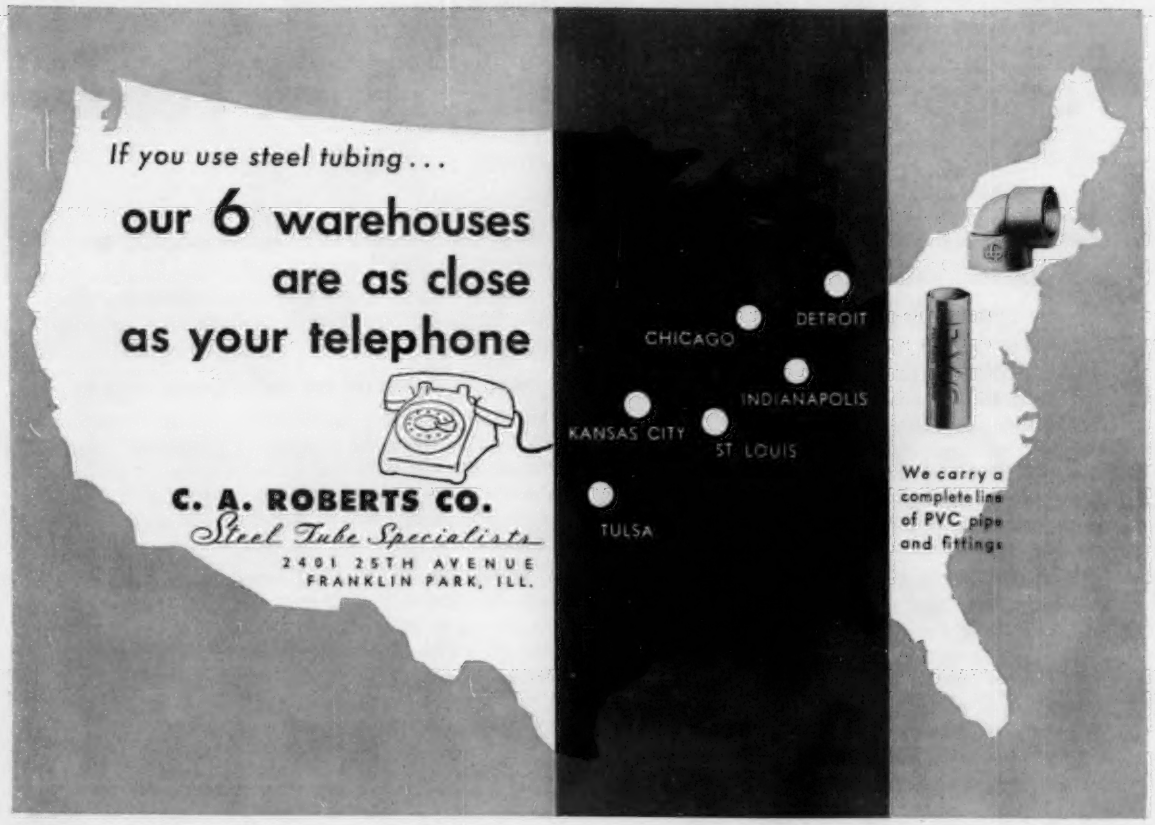
December 17-19 — WINTER MEETING, Palmer House, Chicago, Ill.

February 2-4 — SOUTHEAST SECTION, Memphis, Tenn.

April 3-4 — MID-CENTRAL SECTION, Hotel Robidoux, St. Joseph, Mo.

April 16-18 — FLORIDA SECTION, George Washington Hotel, West Palm Beach, Fla.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.



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135. **Peerless Equipment Co., Inc.,** 1221 E. 5th St., Joplin, Mo.
136. R. H. Pierce Mfg. Co., P.O. Box 528, 245 Blair Blvd., Eugene, Ore.
137. **Pittsburgh Forgings Co.,** Farm Tools Div., Coraopolis, Pa.
138. Prince Mfg. Co., 407 Water St., Sioux City, Ia.
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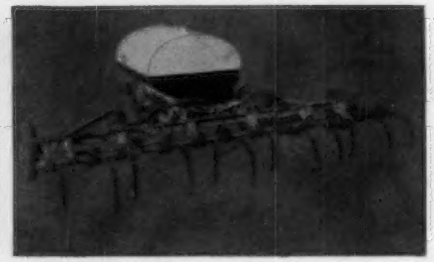

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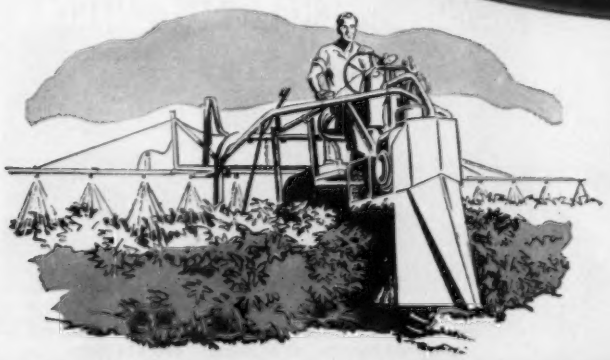

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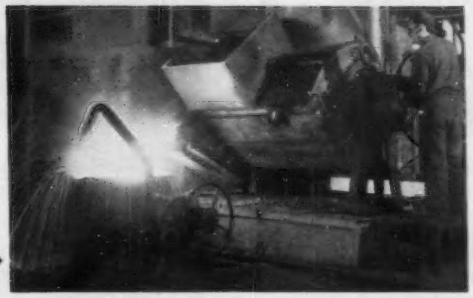

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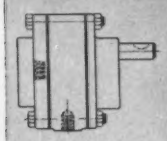

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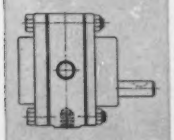

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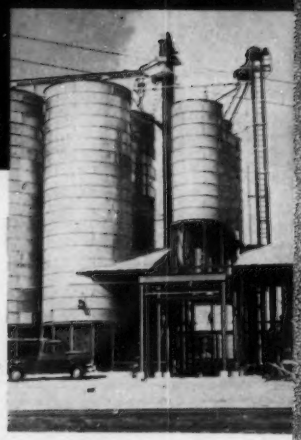

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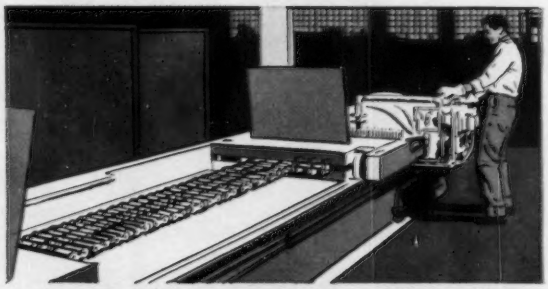

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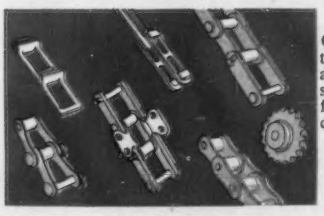

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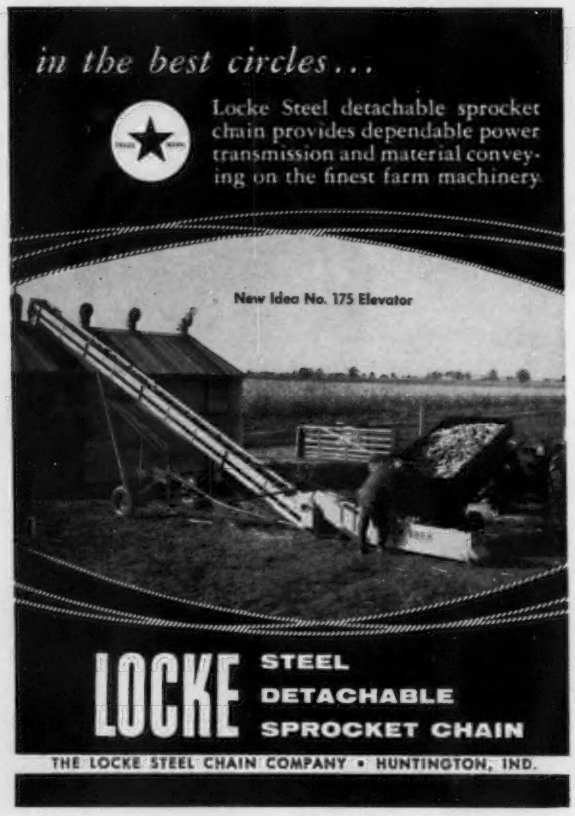
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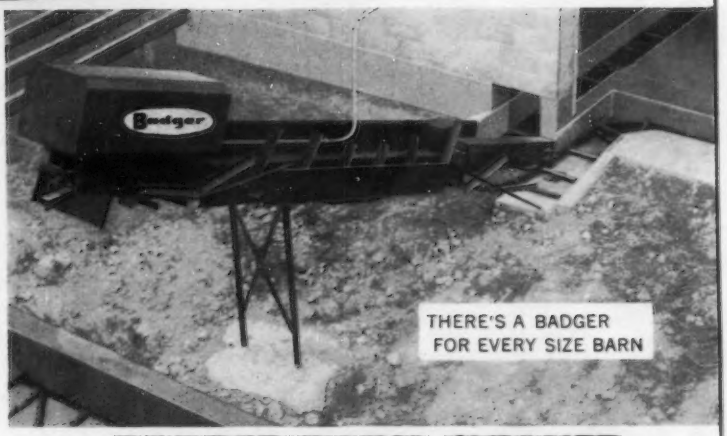

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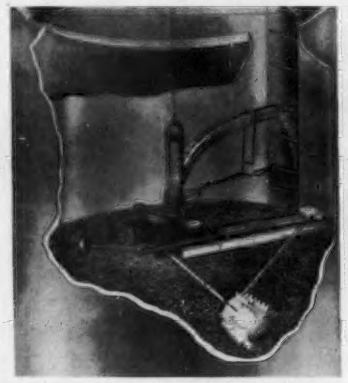

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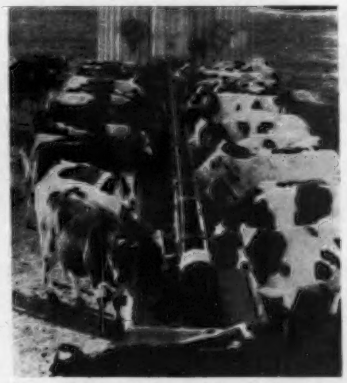

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Basnyat, Tope B. — Agr. engr., Dept. of Agriculture. (Mail) 261 Gyaneswar, Katmandu, Nepal, India

Diaz-Ambrona, Domingo — Engr. of Ministry of Public Works, International Commission on Irrigation and Drainage. (Mail) Agustin Bethencourt, Spain

Ecklund, Harry V.—Account exec., Western Advertising Agency, 610 Wisconsin Ave., Racine, Wis.

Fast, Marion T. — Agr. rep., Douglas Fir Plywood Assn. (Mail) 4101 Thrush Dr, Indianapolis 24, Ind.

Finley, George A. — Pres., Finco, Inc., P.O. Box 968, Aurora, Ill.

Goodman, Robert B. — Supervisor of installation and repair services, Coop. G. L. F. Exchange, Inc. (Mail) R.R. 1, Trumansburg, N. Y.

Hardesty, William E. — Eng. spec., (SCS) USDA. (Mail) P.O. Box 1377, Oklahoma City, Okla.

Howell, Edmund O. — Eng. trainee, New Holland Machine Co. (Mail) Witmer, Pa.

James, Paul E. — Agr. engr., planting and fertilizing equipment and practices section, Agricultural Engineering Laboratory (ARS) USDA, Beltsville, Md.

Knapp, David E. — Dev. engr., John Deere Research & Engineering Center. (Mail) 1603 Mandalay Drive, Cedar Falls, Iowa

Lee, J. Hildred A. — Asst. prof., Ontario Agricultural College, Dept. of Eng. Science, Guelph, Ont., Canada

McGowin, J. Greeley, II — Mgr., retail div., W. T. Smith Lumber Co., Chapman, Ala.

Moilien, Wallace R. — Agr. rep., Caterpillar Tractor Co. (Mail) 986 Simon St., Hayward, Calif.

Nimry, Bassam S. — Asst. irrigation engr., Baker-Harza Eng. Co., P.O. Box 328, Amman, Jordan

Park, Sung W. — Asst. prof., Agricultural College, Seoul National University, Suwon, Korea

Rajatapiti, Metha — Supervisor, Agr. eng. div., rice dept., Ministry of Agriculture. (Mail) c/o Mr. W. M. Kirkpatrick, Jr., California State Polytechnic College, San Luis Obispo, Calif.

Rehkugler, Gerald E. — Asst. prof., agr. eng. dept., Riley-Robb Hall, Cornell Univ., Ithaca, N. Y.

Rick, Norman L. — Agr. engr., Univ. of Minnesota. (Mail) 728 S.E. 6th St., Minneapolis, Minn.

Rogers, Robert W. — Laboratory technician, Ontario Agricultural College, Dept. of Eng. Science, Guelph, Ont., Canada

Ronnfelt, Carl A. — Consultant, Landsbygdens Byggnadsforening, Kindstugatan 1, Stockholm, Sweden

Stone, James F. — Farmer, R.R. 2, Concord, N. H.

(Continued on page 610)

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(Continued from page 609)

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Black, George L. — District mgr., W. R. Ames Co. of Florida. (Mail) P.O. Box 9215, Jackson 3, Miss. (Associate Member to Member)

Bodri, Joseph S.—Design engr., S. L. Allen Co., Inc. (Mail) 23 Violetwood Drive, Levittown, Pa. (Associate Member to Member)

Booker, Samuel H.—Supervisor, rural sales, Alabama Power Co., Birmingham, Ala. (Affiliate to Member)

Donaldson, Marion P. — Service engr., Alabama Power Co. (Mail) 100 Ann St., Enterprise, Ala. (Affiliate to Member)

Edwards, James R. — Service engr., Alabama Power Co., P.O. Box 329, Sylacauga, Ala. (Associate Member to Member)

Mills, William T. — Research asst. prof., agr. engr., agr. eng. dept., Alabama Poly-College, Raleigh, N. C. (Associate Member to Member)

Renoll, Elmo S. — Assoc. prof. and assoc. agr. engr., agr. eng. dept., Alabama Polotechnic Institute, Auburn, Ala. (Associate Member to Member)

Weaver, Wallace C. — District agr. engr., Alabama Power Co. (Mail) 1010 6th Ave., Gadsden, Ala. (Associate Member to Member)

STUDENT TRANSFERS

Allen, James B. — (Univ. of Illinois). U.S. Coast & Geodetic Survey, Washington, D.C.

Anderson, Thomas P. — (Purdue Univ.) (Mail) R.R. 1, Clayton, Ind.

Bolhous, Perry R. — (Univ. of Illinois) c/o Planter Works, John Deere Plow Co., Moline, Ill.

Bonham, Richard L. — Student, Kansas State College. (Mail) 1803 College Heights, Manhattan, Kans.

Bush, Jesse C. — (Alabama Polytechnic Institute). (Mail) 281 E. Thach Ave., Auburn, Ala.

Calhoun, Herman H. — (Louisiana Polytechnic Institute). (Mail) 307 James, Ruston, La.

Constien, Edward J. — (Oklahoma State Univ.). (Mail) Box 49 Vets Village, Stillwater, Okla.

Dowd, Roland P.—(Purdue Univ.). (Mail) c/o A. J. Dowd & Sons, Hartford, Mich.

Goff, Raymon L.—(Purdue Univ.). (Mail) R.R. 3, Lebanon, Ind.

Grim, Leo E. — (South Dakota State College). (Mail) Wagner, S. D.

Hengel, Bernard B. — (South Dakota State College). (Mail) 1004 16th Ave., Brookings, S. D.

Hill, Ronald D. — Asst. agr. engr., Ohio Agriculture Exp. Sta., Ives Hall, Ohio State Univ., Columbus 10, Ohio

Hoer, Ralph A. — (Univ. of Missouri). (Mail) Ralston-Purina Co., Kansas City, Mo.

Mullins, Richard J.—(Iowa State College). (Mail) 224 Ash Ave., Ames, Iowa

Shraibati, Ahmad H. — (Univ. of Missouri). (Mail) 113 Shraibati St., Damascus, Kadam, Syria

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PERSONNEL SERVICE BULLETIN

NOTE: In this bulletin the following listings current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated. "Agricultural Engineer" as used in these listings is not intended to imply any specific level of proficiency or registration as a professional engineer. Items published herein are summaries of mimeographed listings carried in the Personnel Service, copies of which will be furnished on request. To be listed in this Bulletin, request form for Personnel Service listings.

POSITIONS OPEN — MARCH—O-83-807. APRIL O-97-809, 122-811, 121-812, 120-813. MAY — O-129-814, 147-815, 69-817, 132-818, 132-819, 154-820, 159-822. JUNE — O-189-823, 194-824, 199-825, 200-826. JULY — O-256-827. AUGUST — O-266-828, 267-829, 276-830.

POSITIONS WANTED — MARCH — W-80-12. APRIL—W-47-12, 77-14, 98-15, 102-16, 107-17, 94-18, 106-19. MAY — W-25-20, 127-21, 128-22, 143-23, 151-24. JUNE — W-175-26, 186-27, 79-28, 192-29, 172-30, 205-31. JULY — W-197-32, 246-33, 251-35. AUGUST — W-258-38, 236-39, 260-40, 261-41, 242-42, 271-43, 286-44, 285-45, 287-46.

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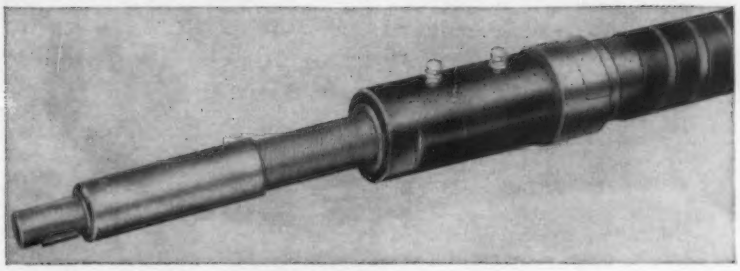
MECHANIC and TROUBLE SHOOTER for work with engineers for manufacturer of farm mechanical equipment. Any location. Married. Age 44. No disability. Training and experience in submarine service 4 yr and with ship builder on test of engines, pumps, and hydraulic equipment. Operated own repair shop 10 years, doing general repair from lawn mowers to diesel tractors. Available on reasonable notice. Salary open. W297-48

CHEMICAL ENGINEER for development or research in product processing with college, manufacturer, or processor. Any location. Single. Age 26. No disability. BSChE, 1958, Michigan College of Mining and Technology. Work experience as detail draftsman, one summer. Grocery store manager 3 yr. Required military service completed. Available on reasonable notice. Salary $450 per mo. W-299-49

AGRICULTURAL ENGINEER for design, development, research, writing, or management with industry in Southwest or West. Will travel part time. Married. Age 33. Vision corrected by glasses. BSA, 1950; BSME, 1951, University of Maryland. Farm background in mechanized farming. Taught food processing machinery courses half time, two years, University of Maryland. Teaching and extension in agricultural engineering, one year, University of Delaware. Self-employed farm equipment dealer 2¼ yr. Assistant plantation engineer 3¾ yr with Hawaiian pineapple producer. War enlisted and commissioned service 3 yr with Naval Air Arm. Available on 30 days notice. Salary open. W-248-50

AGRICULTURAL ENGINEER for design, development or research in power and machinery or soil and water field with experiment station or manufacturer. Any location. Citizen of India. Single. No disability. MSAE, University of Illinois. Experience as graduate assistant. Available now. Salary open. W-302-51

HOW TO SELECT FLEXIBLE SHAFTING FOR POWER DRIVE APPLICATIONS



1¼-inch STOW Power Drive flexible shaft with core assembly pulled out of casing.

For Power Drive applications, the following factors must be considered:

1. Torque (Lb. in.) to be transmitted. (The starting torque should be used in making selections).

2. Operating Speeds (RPM)—If the maximum speed is higher than the rated speed, torque ratings in the table below do not apply. To find the torque capacity for flexible shafts operating at speeds higher than the rated speeds, multiply the maximum dynamic torque capacity by the rated speed, and then divide by the operating speed. (See example).

3. Operating Radius—In making the selection from the table below, the radius of the smallest bend in the flexible shaft should be used.

Ratings — The ratings for flexible shafts shown in the table below apply under the following conditions:

1. When the flexible shaft is adequately supported by clamps along its length. (For unsupported shafts, multiply the calculated torque by a safety factor of 1.6—see example below)

2. When the flexible shaft is operated in the wind-up direction, which tends to tighten the outer layer of wires. (Flexible shafts operated in the unwind direction will transmit only about 60% of the rated torque).

3. When the flexible shaft is in continuous operation. Note: **the ratings are based on temperature rise. When the operation is intermittent, the ratings in the table may be exceeded. Consult Stow Engineers for specific recommendations.**

RATED SPEED R.P.M.	MAXIMUM DYNAMIC TORQUE CAPACITY (LB. IN.) STRAIGHT AND CURVED SHAFTS RADIUS OF CURVATURE IN INCHES									Wgt./ C. Ft.	Core Dia.	Core No. and Type	Shaft Size
	50 to Strgt.	25	20	15	12	10	8	6	5				
4,500	2.4	2.2	2.0	2.0	1.92	1.9	1.7	1.5	1.25	3.0	.124/.128	2049 MH	13
3,800	7.0	6.4	6.0	5.8	5.4	5.0	4.6	3.6	2.0	4.5	.148/.152	2081 MH	15
2,900	9.4	8.6	8.0	7.6	7.0	6.6	6.0	4.8	3.4	7.0	.185/.189	5108 MH	19
2,500	22.0	20.0	18.8	17.6	16.0	15.0	12.6	10.8	9.0	12.5	.247/.252	8924 MH	25
1,800	30.0	28.0	26.4	25.0	23.0	21.0	18.0	14.0		20.0	.308/.313	8925 MH	31
1,800	33.8	31.5	29.7	28.1	25.9	23.6	20.2	15.8		20.0	.308/.313	8969 T	31
1,800	36.0	33.0	31.6	30.0	28.0	26.0	22.0	18.0	11.0	21.0	.324/.329	2034 A	31
1,500	80.0	66.0	63.0	58.0	51.0	46.0	37.0	22.0		28.5	.368/.374	2035 A	38
1,500	60.0	54.0	50.0	46.0	42.0	38.0	30.0	24.0		29.0	.387/.393	8970 MH	40
1,500	90.0	81.0	75.0	69.0	63.0	57.0	45.0	36.0		29.0	.387/.393	8971 T	40
1,150	136.0	110.0	104.0	94.0	80.0	72.0	56.0			50.5	.497/.503	8999 A	50
1,150	148	124	110	92	72	56				53.5	.505/.511	6940 T	50
900	248	200	176	124	84					78.5	.610/.618	6997 T	63
900	220	204	192	180	152	130				80.5	.630/.638	7731 A	63
750	340	224	156	76						117	.747/.753	2056 T	75
600	760	520	420							205	.998/1.004	2057 T	100
440	1,500	720								343	1.298/1.304	2058 T	125

EXAMPLE — How to use the table:

The problem is to transmit ½ H.P. at 1700 RPM through an unsupported flexible shaft in a 25" radius, estimated starting torque 150% of normal operating torque.

1. Calc. Torque (lb. in.)—

$$\frac{HP \times 63000}{RPM} = \frac{.5 \times 63000}{1700} = 18.5$$

2. Correction factor for starting torque 1.5 x 18.5=27.75

3. Correction factor for unsupported shaft 27.75 x 1.6 = 44.4 lb. in.

4. Refer to Table above. Read downward in column under 25" radius until you find a core having a rating of at least 44.4 lb. in. In this case we find that core No. 8970 is rated 54 lb. in. at 1500 RPM. Since the given speed is 1700 RPM, multiply 54 by 1500 and divide by 1700. 54 × 1500 ÷ 1700 = 47.6 lb. in. (rated torque at 1700 RPM). Therefore, Core No. 8970 is correct.

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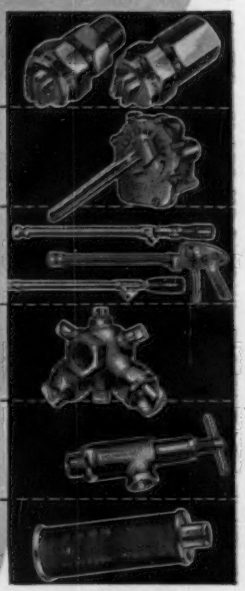

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Federal-Mogul-Bower Bearings, Inc.

(For more facts circle No. 78 on reply card)

New mower transmission uses TIMKEN® bearings throughout—even on pitman

New, smaller-design Timken bearings help John Deere gain economy and rugged dependability in mower design.

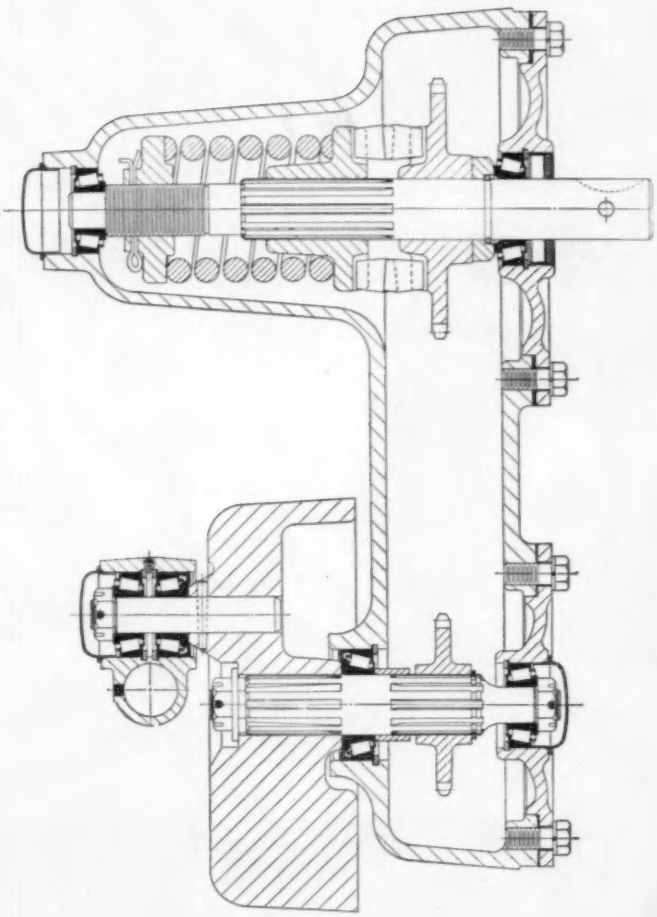
JOHN DEERE engineers know that Timken® bearings are designed and made to take the pounding shock and impact inherent in mower operation, especially in the pitman. By using the new, smaller standardized-size Timken Moto-Mated bearings, John Deere was able to keep its pitman design compact and also get vibrationless operation on its new No. 8 and No. 9 mowers.

These smaller, lighter, capacity-packed Timken Moto-Mated bearings save space and weight, permit more compact design. And because they're produced by revolutionary new methods, they cost less than previous designs.

Timken bearings are also used on the input shaft and crankshaft of the new mowers to assure accurate alignment under severe operating conditions. To get positive sealing and to minimize space, John Deere uses Timken bearings with the new "Duo-face" seal at the inner pitman position, adjacent to the flywheel on the crankshaft. This new bearing-seal unit gives 2-way sealing. It also cuts installation costs because it is pre-assembled.

Timken tapered roller bearings are geometrically designed and precision-made to roll true. Their taper lets them take both radial and thrust loads in any combination. They give agricultural engineers money-saving answers to design problems involving 1) loads, 2) dirt, 3) ease of operation.

Field Engineering Service. Our Sales Engineers, all thoroughly trained bearing application engineers, will gladly check your farm machine design and application drawings with you. They'll recommend the Timken bearings that will give you the best performance and economy. The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable: "TIMROSCO".



NOT JUST A BALL NOT JUST A ROLLER THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL AND THRUST—LOADS OR ANY COMBINATION

The farmer's assurance of better design

Tapered Roller TIMKEN BEARING EQUIPPED

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